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THE COST OF CLEAN AIR

ANNUAL REPORT

of the

ADMINISTRATOR
ENVIRONMENTAL PROTECTION AGENCY

to the

CONGRESS OF THE UNITED STATES

In Compliance with
Public Law 91-604

APRIL, 1973

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PREFACE

This report, the fifth submitted to Congress, complies with Section 312(a) of the Clean Air Act, as amended by Public Law 91-604, the Clean Air Amendments of 1970, and is the third prepared under the direction of the Administrator of the Environmental Protection Agency. Section 312(a) reads as follows:

> "Sec. 312(a). In order to provide the basis for evaluating programs authorized by this Act and the development of new programs and to furnish the Congress with the information necessary for authorization of appropriations by fiscal years beginning after June 30, 1969, the Administrator, in cooperation with State, interstate, and local air pollution control agencies, shall make a detailed estimate of the cost of carrying out the provisions of this Act; a comprehensive study of the cost of program implementation by affected units of government; and a comprehensive study of the economic impact of air quality standards on the Nation's industries, communities, and other contributing sources of pollution, including sources of pollution, including an analysis of the national requirements for and the cost of controlling emissions to attain such standards of air quality as may be established pursuant to this Act or applicable State law. The Administrator shall submit such detailed estimate and the results of such comprehensive study of cost for the five-year period beginning July 1, 1969, and the results of such studies, to the Congress not later than January 10, 1969, and shall submit a re-evaluation of such estimate and studies annually thereafter."

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CHAPTER 1: INTRODUCTION AND SUMMARY

I. PURPOSE AND SCOPE

This report to Congress, submitted in accordance with the Clean Air Act Amendments of 1970, presents projections of the costs and the results of governmental and private efforts to carry out provisions of the Act. The projections cover fiscal years 1974 through 1978, i.e., from July 1, 1973 to July 1, 1978.

The sources of air pollution ~~may~~ be broadly divided into three groups: transportation sources, power sources, and production or industrial sources. Projections for each of these groups are presented in separate chapters of this report.

As in previous reports, national cost estimates are presented for governmental programs and for control of sources of air pollution. Coverage has been expanded to include not only those pollutants for which national ambient air quality standards have been promulgated, but also pollutants covered by proposed hazardous air pollutant emission standards and by new source performance standards.

Apparent similarities notwithstanding, this report also differs from its predecessors in several important respects. Estimates of costs, benefits, and impacts reported herein are based, insofar as possible, upon actual regulations adopted by the States in implementation plans submitted to EPA. In previous reports, these estimates have been based on an assumed nationally applicable set of regulations.

All costs are presented in this report in 1970 dollars. The year 1970 was judged as the appropriate baseline for this work, although previous reports were submitted with 1967 as the baseline. This change is in keeping with the passage of the clearer and more specific Clean Air Amendments of 1970, and with the wording of Section 312(a) of that legislation, as may be seen from the preface to this report. Coincidentally, 1970 was a census year, permitting us to use more precise baseline data than hitherto possible.

By no means should it be presumed that all costs of abating air pollution are included in this report. Even before the Clean Air Act of 1963, costs were incurred in response to obvious pollution problems and to local legislation. Therefore, the costs presented herein are incremental costs, over the cost of control as legislated prior to 1970.

TABLE 1-1. Ambient Air Quality Standards*

Pollutant	Primary (Health) have 3 years to reach	Secondary (Welfare); no deadline
Particulates:		
Annual mean	75	60
Maximum 24-hr. concentration..	260	150
Sulfur oxides:		
Annual mean..................	80	-
Maximum 24-hr. concentration..	365	260
Maximum 3-hr. concentration...	-	1300
Carbon monoxide:		
Maximum 8-hr. concentration...	10	10
Maximum 1-hr. concentration...	40	40
Photochemical oxidants:		
Maximum 1-hr. concentration...	160	160
Hydrocarbons:		
Maximum 3-hr. concentration, 6 to 9 a.m..................	160	160
Nitrogen dioxide:		
Annual mean..................	100	100

*From Federal Register, April 30, 1971. Concentrations for pollutants in micrograms per cubic meter except for carbon monoxide, in milligrams per cubic meter.

anticipated that seven other classes of stationary sources will soon be added to this list. These are asphalt concrete plants, petroleum refineries, petroleum refineries storage vessels, brass and bronze refineries, iron and steel mills, sewage sludge incinerators and secondary smelters of lead. Table 1-2 lists the new source performance standards existing and proposed, for these stationary sources.

Hazardous air pollutants are singled out for specific treatment. Currently, emission limits have been proposed for three such pollutants. These are asbestos, beryllium and mercury. For operations using asbestos, various processes would be prohibited, visible emissions of particulate matter would be prohibited and fabric filter control, or equivalent, would be required. For operations involving beryllium of beryllium containing materials, the proposed limits provide that beryllium emissions to the atmosphere shall not exceed 10 gms/24 hrs or, alternatively, the maximum concentration of beryllium in the air shall not exceed 0.01 micrograms per cubic meter, averaged over a 30 day period. (Exceptions to these limits would be provided for firing of beryllium propellants at rocket motor sites.) For operations involving elemental mercury, emissions would not be permitted to exceed 2300 grams of mercury over 24 hours.

TABLE 1-2. New Source Performance Standards

Source	Emission Standard
Fossil Fuel-Fired Steam Generators	
Particulates	0.1 lb/10^6Btu
Sulfur dioxide	
liquid fuel	0.8 "
Solid Fuel	1.2 "
Nitrogen oxides	
Gaseous fuel	0.2 "
liquid fuel	0.3 "
Solid fuel	0.7 "
Visible emissions	#1 Ringel. or 20% Opacity
Incinerators	
Particulates	0.08 gr/SCF
Portland Cement	
Particulates	
Kilns	0.3 lb/ton feed
Clinker coolers	0.1 "
Visible emissions	
Kilns	#1/2 or 10% Opacity
Others	10% Opacity
Nitric Acid	
Nitrogen oxides	3.0 lb/ton acid
Visible emissions	10% Opacity
Sulfuric Acid	
Sulfur dioxide	4.0 lb/ton acid
Acid mist	0.15
Visible emissions	10% Opacity
Asphalt Concrete	
Particulates	0.03 gr/SCF
Visible emissions	10% Opacity
Petroleum Refineries	
Particulates from fluid catalytic cracking	0.02 gr/SCF
Hydrogen sulfide content of fuel gas	10 gr/100 SCF
Storage Vessels	
Require floating roof	1.5 psia vapor pressure
Require vapor recovery	11 psia vapor pressure
Brass and Bronze Refineries	
Particulates	0.02 gr/SCF

TABLE 1-2. New Source Performance Standards--Continued

Source	Emission Standard
Iron and Steel Mills	
Particulates	0.02 gr/SCF
Particulates, basic oxygen furnace	0.1 lb/ton of steel
Sewage Sludge Incinerators	
Particulates	0.03 gr/SCF 10% Opacity
Secondary Lead Smelters	
Particulates	0.02 gr/SCF

The first five categories of source standards apply to installations constructed or modified after August 17, 1971. The remaining categories have not been formalized.

Motor vehicle emissions have been the subject of specific standards of emission control since the 1968 model year. New limits have been set for automobiles, which were to have been applied to the 1975 models and later. These standards will bring about a 90% reduction from allowed levels for 1970 models in hydrocarbons and carbon monoxide emissions for 1975 models, and a 90% reduction from levels for 1971 models in nitrogen oxides emissions beginning with 1976 models.

The standards to accomplish these reductions call for an emission limit of 3.4 grams of carbon monoxide and 0.41 grams of hydrocarbons per vehicle mile beginning with 1975 models. Nitrogen oxide emissions are limited to 3.0 grams/mile beginning with 1973 models, and 0.4 grams/mile beginning with 1976 models. However, the 1975 hydrocarbon and carbon monoxide standards were postponed for a year with interims standards set for 1975 as described on p.4-1; Hearings are currently underway on whether the 1976 oxides of nitrogen standards should be suspended for one year. Somewhat different standards are applicable to heavy duty vehicles.

III. COSTS OF IMPLEMENTING THE ACT

Estimates of the investments for implementing the Act over the period FY 1970-1978, and the annualized cost in FY 1978 are summarized in Table 1-3. Each number in the table is repeated in the appropriate chapter of this report, where the assumptions and data on which the estimate is based are presented. Concomitant projected decreases in emissions from those which would have

TABLE 1-3. NATIONAL EMISSION REDUCTIONS AND COSTS UNDER STATE AND NATIONAL STANDARDS FOR FISCAL YEAR 1978 (COST IN 1970 DOLLARS) 1/

Source Class Type	Emission Level without further control 1/ (Thousands of Tons per Year)					Decrease of Emission Level (Percent) 2/					Total Control Cost (Millions of Dollars in FY 78) 3/	
	Part	SO_x	CO	HC	NO_x	Part	SO_x	CO	HC	NO_x	Investment	Annual
Mobile Sources 4/	900	1,150	159,300	27,850	16,250	0	0	14	6.6	7.5	13,920	6,465
Solid Waste Disposal	2,981	-	5,320	7,283	-	93	-	88	87	-	512	242
Sewage Incinerators	12	-	-	-	-	98	-	-	-	-	12	2
Stationary Fuel Combustion:												
Small & Intermediate Boilers	6,867	7,774	-	-	2,069	82	79	-	-	40	879	1,342
Steam-electric power	4,083	28,150	-	-	16,053	88	81	-	-	15	2,900	1,860
TOTAL	14,843	37,074	164,620	35,133	34,372	12,008	22,801	4,682	8,174	2,408	18,223	9,911
Industrial Process Studied:												
Asbestos	707	-	-	-	-	84	-	-	-	-	8	3
Asphalt Batching	2,184	-	-	-	-	72	-	-	-	-	306	70
Cement	432	-	-	-	-	91	-	-	-	-	184	73
Coal Cleaning	71	-	-	-	-	94	-	-	-	-	27	3
Forest Products	84	-	275	23	2	80	-	85	0	0	71	7
Ferroalloys	111	-	-	-	-	98	-	-	-	-	249	66
Grain Plants: Handling	1,306	-	-	-	-	98	-	-	-	-	537	113
Feed	233	-	-	-	-	98	-	-	-	-	22	4
Gray Iron Foundries	61	-	586	-	-	80	-	90	-	-	581	168
Iron and Steel	690	-	4,092	-	-	93	-	0	-	-	526	179
Kraft (Sulfate) Pulp	960	-	-	-	-	92	-	-	-	-	108	46
Lime	687	-	-	-	-	88	-	-	-	-	45	13
Natural Gas	-	540	-	-	-	-	96	-	-	-	44	12
Nitric Acid	-	-	-	-	115	-	-	-	-	90	17	5
Petroleum Products & Storage	-	-	-	2,043	-	-	-	-	60	-	159	0
Petroleum Refineries	225	4,403	10,490	169	-	60	98	69	95	-	335	46
Phosphate	348	-	-	-	-	91	-	-	-	-	40	23
Primary Non Ferrous Metallurgy:												
Copper	79	4,451	-	-	-	95	81	-	-	-	818	178
Lead and Zinc	51	570	-	-	-	96	50	-	-	-	45	12
Mercury	15	-	-	-	-	93	-	-	-	-	.4	.06
Aluminum	75	-	-	-	-	96	-	-	-	-	796	209

TABLE 1-3 - FOOTNOTES

1/ Standards given in Section 1-B. Blanks in the table indicate that emission levels meet applicable regulation or that emissions are negligible or do not exist.

2/ Emission abbreviations are: particulates (Part), sulfur oxides (SO_x), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x). Decrease column is not total efficiency, as given in text, but incremental efficiency over 1970 levels.

3/ Projected costs are the initial investment expenditures from 1970 to 1978 for purchasing and installing control equipment (total investment) and the continuing annual costs for interest, property taxes, insurance, depreciation, etc., and for operating and maintaining of equipment (ultimate annual cost). Costs of government programs and for monitoring operations are not included.

4/ Includes highway vehicles, aircraft, rail, and vessels. Control of particulate and sulfur oxides from mobile sources was not considered in this study.

5/ Forest fires, structural fires, coal refuse fires, solvent evaporation, agriculture burning, stone and gravel, limestone, etc.

6/ To nearest 10,000 tons.

obtained in 1978 were no further progress made in implementing the Act are also presented in Table 1-3.

It is not possible to estimate actual cash outlays over the reporting period with any precision since the compliance schedules for implementation of state plans are not yet determined. The earlier implementation is commenced, the larger will be the cash outlay over the period because operation and maintenance expenses will be incurred for more years.

The current report includes cost estimates for more sources of pollution and more pollutants than did the previous report. This is evident in Table 1-3, and in the tables of chapter 5 in particular. As well, the costs are on a more definite basis than was possible in earlier studies. Cost estimates in the current report are based largely on actual state regulations, whereas those in previous reports have been based on assumed regulations.

Estimates of the cost per vehicle of attaining Federal automotive emission standards becoming effective in 1975 and 1976 have been revised downward. A more complete discussion of the factors entering into this cost may be found in chapter IV.

IV. BENEFITS OF IMPLEMENTING THE ACT

In gathering the costs of air pollution control for this report, we have become very conscious of the uncertainties involved in forecasting even five years into the future. Our evaluations are based on present technology, with no allowance for innovation. Each cost is simply an extrapolation of current practice, and rarely in this century would such a five-year extrapolation have held true.

To estimate dollar values for the benefits accrued as a result of these costs would be even more difficult. Air pollution has clearly observable effects; these are discussed in Chapter 2. The measures of these effects appear in terms of increased morbidity and mortality, a deterioration of aesthetic qualities, and damage to artifacts. How does one establish the value of one's health or a work of art imperiled by air pollution? Attempts have been made to answer these questions, but at present the estimates have wide ranges and little reliability.

Even if benefits accrued could be estimated, a future benefit beyond 1978 can be credited to many of the investments reported herein. The time to suppress air pollution is in its early stages, not when it becomes so dense that current benefits clearly outweigh current costs. With population growth and increased industrialization, future pollution control will rely on the technology and practices being initiated today. This redirection, bringing attention to the need for clean air, may turn out to be the greatest benefit of implementing the Act.

CHAPTER 2: EFFECTS OF AIR POLLUTION

I. INTRODUCTION

The cost outlays projected in other chapters of this report are associated with large reductions in emissions from air pollution sources. These emission reductions are expected to result in substantial improvement in ambient air quality. It is well known that differences in ambient air quality are associated with differences in incidences of mortality and morbidity, decreases of soiling and corrosion, yields of agricultural products, and residential property values. It was on the basis of the latest available scientific information on the health and welfare effects of air pollutants* that EPA promulgated the National Ambient Air Quality Standards given in Table 1-1 (Chapter I).

This chapter reviews the health and welfare effects of air pollutants now being regulated by EPA. Achievement of the National Ambient Air Quality Standards will eliminate damaging effects on human health and welfare and return substantial benefits to society.

II. HEALTH AND WELFARE

A. Particulates

1. Effects on Health

Analyses of numerous epidemiological studies clearly indicate the association between air pollution, as measured by particulate matter accompanied by sulfur dioxide, and health effects of varying severity. This association is most firm for the short-term air pollution episodes.

For the most part, the effects of particulate air pollution on health are related to injury to the surfaces of the respiratory system. Such injury may be permanent or temporary.

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* Reported in National Air Pollution Control Administration Publication Nos. AP-49 (Particulate Matter), AP-50 (Sulfur Oxides), AP-62 (Carbon Monoxide), AP-63 (Photochemical Oxidants), AP-64 (Hydrocarbons), and AP-84 (Nitrogen Oxides).

Increase in daily death rates and a considerable increase in illness have been observed at smoke levels above 750 micrograms per cubic meter (ug/m^3). (Sulfur oxides pollution levels were also high in most cases studied.) These unusual short-term, massive exposures result in immediately apparent pathologic effects, and they represent the upper limits of the observed dose-response relationship between particulates and adverse effects on health.

Daily averages of smoke above 300 ug/m^3 to 400 ug/m^3 have been associated with acute worsening of chronic bronchitis patients. Studies have found that increased absences due to illness occurred when smoke levels exceeded 200 ug/m^3.

The lowest particulate levels at which health effects appear to have occurred in this country are reported in studies conducted in Buffalo and Nashville. The Buffalo study clearly shows increased death rates from selected causes in males and females 50 to 69 years old at annual geometric means of 100 ug/m^3 and over. The Nashville study suggests increased death rates for selected causes at a coefficient of haze above 1.1. Sulfur oxides pollution was also present during the periods studied.

2. Effects on Climate and Visibility

Particles suspended in the air scatter and absorb sunlight, reducing the amount of solar energy reaching the earth, producing hazes and reducing visibility. Suspended particulate matter plays a significant role in bringing about precipitation, and there is some evidence that rainfall in cities has increased as the cities have developed industrially.

At concentrations ranging from 100 ug/m^3 to 150 ug/m^3 for particulates, where large smoke turbidity factors persist in middle and high latitudes, direct sunlight is reduced up to one-third in summer and two-thirds in winter. At concentrations of about 150 ug/m^3 visibility is reduced to as low as 5 miles.

3. Effects on Materials

Particulate air pollution causes a wide range of damage to materials. Particulate matter may chemically attack materials through its own instrinsic properties, or through the properties of substances adsorbed or adsorbed on it. Merely by soiling materials, and thereby causing more frequent cleaning, particulates can accelerate deterioration.

Particulates play a role in the corrosion of metals. At particulate concentrations ranging from 60 ug/m^3 to 180 ug/m^3 (annual geometric means), corrosion of steel and zinc panels occurs at an accelerated rate in the presence of sulfur dioxide and moisture.

4. Effects on Vegetation

Relatively little research has been carried out on the effects of particulate air pollution on vegetation, and much of the work that has been performed has dealt with specific dusts, rather than with the conglomerate mixture normally encountered in the atmosphere. Some specific studies have shown that cement-kiln dusts can damage plants and change soil alkalinity. Dust deposits may interfere with pollen germination and be harmful to the health of animals that feed on such species.

B. Sulfur Oxides

1. Effects on Health

The current scientific literature indicates that, for the most part, the effects of sulfur oxides on health are related to irritation of the respiratory system. Such injury may be temporary or permanent.

Laboratory studies show that sulfur dioxide can produce bronchoconstriction in experimental animals.

Laboratory observations of respiratory irritations suggest that most individuals will show a response to sulfur dioxide when exposed for 30 minutes to concentrations of about 14 milligrams per cubic meter (mg/m^3) and above. Exposure of certain sensitive individuals to about 3 mg/m^3 can produce detectable changes in pulmonary function. Similar exposure of these same individual has, in some instances, produced severe bronchospasm.

Studies of episodes suggest that a rise in the daily death rate occurred when the concentrations of sulfur dioxide rose abruptly to levels at or about 715 ug/m^3. Daily concentrations of sulfur dioxide in excess of 1500 ug/m^3 for one day in conjunction with levels of suspended particles exceeding 2000 ug/m^3 appear to have been associated with an increase in the death rate of 20 percent or more over base line levels. This same effect has been observed at lower sulfur dioxide levels when the maximum pollution levels lasted for a longer period.

At concentrations ranging from 300 ug/m^3 to 500 ug/m^3 of sulfur dioxide (24-hour mean), with low particulate levels, increased hospital admissions of older persons for respiratory disease have been noted; absenteeism from work, particularly with older persons, also has been noted. At lower levels, i.e. at concentrations as low as 105 ug/m^3 to 120 ug/m^3, there have been observations of increased frequency and severity of respiratory symptoms and lung disease.

2. Effects on Materials

Sulfur oxides air pollution causes a wide range of damage to materials. Most field studies have obtained data on the combination of particulate and sulfur oxides pollution. On the basis of present knowledge, it is difficult to evaluate precisely the relative contribution of each of the two classes of pollution; however some general conclusions may be drawn.

Sulfur oxides pollution has been specifically associated with damages to metals, cotton, finishes, coatings, building stone, paints, paper and leather. At a SO_2 level of 345 ug/m^3, accompanied by high particulate levels, the corrosion rate for steel panels may be increased by 50 percent. Damage to electrical equipment has been reported, and effects on a wide variety of building materials as well as statuary and other works of art have been observed.

3. Effects on Vegetation

Sulfur dioxide may cause acute or chronic leaf injury to plants. After exposure to about 860 ug/m^3 of sulfur dioxide for 8 hours, some species of trees and shrubs show injury. At concentrations of about 145 ug/m^3 to 715 ug/m^3, sulfur dioxide may react synergistically with either ozone or nitrogen dioxide in short-term exposures (e.g., 4 hours) to produce moderate to severe injury to sensitive plants. At still lower concentrations, i.e. about 85 ug/m^3 of sulfur dioxide (annual mean), chronic plant injury and excessive leaf drop may occur.

C. Carbon Monoxide

1. Effects on Health

People most susceptible to the adverse effects of atmospheric CO are those most sensitive to decreased oxygen supply. These susceptible groups include individuals with anemia, cardiovascular disease, anormal metabolic states such as thyrotoxicosis or fever, and chronic pulmonary disease, and the developing fetus. Current studies are probing the effect of CO on the cardiovascular system. Results indicate that CO exposure restricts maximum heart beat rate, and therefore maximum physical performance, and that it aggravates angina pectoris.

Carbon monoxide levels in high traffic streams often rise to 50 ppm or more. These levels possibly deteriorate the visual and motor responses of drivers and hence contribute to accidents. Under Coordinating Research Council (CRC) contracts, two groups are studying how human response suffers under exposure to CO.

A Harvard University group is studying human visual adaptive responses to doses of CO. Evidence indicates that peripheral vision and glare recovery suffer after exposure to CO. An Ohio State University group has found that human attention to driving conditions also suffers.

2. Other Effects

There have not been any studies associating carbon monoxide with damages to materials.

Carbon monoxide has not been shown to produce detrimental effects on the higher-type plant life at concentrations below 115 mg/m^3 during exposures for 1 to 3 weeks. Nitrogen fixation by efficient nitrogen-fixing bacteria in clover roots was inhibited by 115 mg/m^3 CO when exposed for 1 month.

Ambient CO levels rarely reach 115 mg/m^3 even for very short period of time. In view of this and other information concerning CO effects, a significant impact on vegetation and associated microorganizms seems improbable.

D. Photochemical Oxidants

1. Effects on Health

Sunlight induces photochemical reactions in the atmosphere between the hydrocarbons and oxides of nitrogen emitted by pollution sources. These reactions generate, among other products, the two major pollutants ozone and peroxyacetyl nitrate. It is difficult to separate the effects of these chemicals from the effects of their parent pollutants. In this chapter, they are lumped together as photochemical oxidants (symbol O_x).

Epidemiological studies have identified adverse health effects as a result of increased atmospheric levels of photochemical oxidants. Under conditions prevailing where studies were conducted, impairment of performance of student athletes occurred over a range of hourly average oxidant concentrations from 60 to 590 ug/m^3. A small number of asthmatics suffered an increased frequency of attacks when peak oxident concentrations exceed 250 ug/m^3, a level equivalent to an hourly average concentration ranging from 100 to 120 ug/m^3. Eye irritation was reported by subjects in several studies when photochemical oxidant concentrations reached instantaneous levels of about 200 ug/m^3, a level associated with an hourly average concentration ranging from 60 to 100 ug/m^3.

2. Effects on Materials

The effects of oxidants on materials is discussed below. Frequently, damage occurs when two or more pollutants are present and it is difficult to estimate the relative effects of each. Estimated damage costs are included for some of the material effects discussed below.

(1) Elastomers. Perhaps the primary materials damage attributable to ozone is that on elastomers, primarily rubber. The cost attributed to the aging and premature failure of rubber products due to ozone is $500 million annually.[1]

(2) Textiles. Photochemical oxidants (primarily ozone) and NO_x cause fading of textile dyes. To combat this, dye manufacturers have to go to the extra expense of adding anti-oxidant compounds to their dyes.

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[1] Mueller, J.W. and Stickney, P.B. "A Survey and Economic Assessment of the Effects of Air Pollution on Elastomers," Contract OPA-22-69-146, Battelle Memorial Institute, June 25, 1970.

(3) Paints. Ozone and NO_x cause damage to painted surfaces. The total annual air pollution damages to paints is estimated at $0.7 billion,[1] but the fraction of this damage attributable to ozone is not known. Not included are the damaging effects of pollution on painted and glazed surfaces of highly valued works of art.

(4) Corrosion of Metals. A Battelle Memorial Institute study[2] of air pollution effects on metals stated that total damage due to pollution-related corrosion was $1.45 billion per year. Again the fractions attributable to ozone and other photochemical oxidants are not known. Indications are that ozone has a role in the degradation of steel, aluminum, and copper, but not zinc.

3. Effects on Vegetation

Adverse effects on sensitive vegetation were observed from exposure to photochemical oxidant concentrations of about 100 ug/m^3 for 4 hours. Injury to vegetation is one of the earliest manifestations of photochemical air pollution, and sensitive plants are useful biological indicators of this type of pollution.

E. Hydrocarbons

1. Effects on Health

Studies conducted so far, do not demonstrate any direct health effects of gaseous hydrocarbons (in the air).

However, ambient levels of photochemical oxidants, which do have adverse effects on health, are directly related to concentrations of gaseous hydrocarbons. Therefore, the contribution of hydrocarbons to the formation of oxidants should be taken into account when considering health effects.

2. Effects on Materials and Vegetation

As in effects of health, the contribution of hydrocarbons to the formation of photochemical oxidants and resultant health effects must be considered. In the absence of ozone, only ethylene has had adverse effects at known ambient concentrations. Injury to sensitive plants has been reported in association with ethylene concentrations of from 1.15 to 575 ug/m^3 over a time period of 8 to 24 hours.

F. Nitrogen Oxides

1. Effects on Health

Both of the prominent oxides of nitrogen present in ambient air are potential health hazards. At ambient concentrations, NO presents no direct threat to general health; the greatest toxic potential for NO at ambient concentrations is related to its tendency to undergo oxidation to NO_2. Nitrogen

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2/ Fink, F.W., Buttner, F.H., and Boyd, W.K. "Technical-Economic Evaluation of Air Pollution Corrosion Costs on Metals in the U.S." Battelle Memorial Institute, Columbus, Ohio, February 19, 197 .

dioxide, NO_2, can be significantly correlated with increased respiratory disease at mean 24-hour concentrations between 117 and 205 ug/m^3.

The frequency of acute bronchitis increased among infants and school children when the range of mean 24-hour NO_2 concentrations, measured over a 6-month period, was between 119 and 157 ug/m^3, and the mean suspended nitrate level was 2.6 ug/m^3 or greater.

2. Effects on Materials

Damage to materials has been attributed to the oxides of nitrogen in ambient atmospheres. Effects on dyes and paints specifically, have been attributed to NO_x; however, the precise air concentrations producing these effects have not been determined. Nitrate compounds have also been identified with corrosion and failure of electrical components.

3. Effects on Vegetation

Adverse effects on vegetation such as leaf abscission and decreased yield of navel oranges have been observed when the NO_2 concentration was 470 ug/m^3 during an 8-month period. Exposure to higher concentrations, e.g. 1 ppm, can cause overt leaf injury to sensitive plants.

CHAPTER 3: GOVERNMENTAL PROGRAMS

I. INTRODUCTION

This chapter reports projected costs of governmental programs directed toward implementation of the purposes of the Clean Air Act Amendments of 1970.

II. FEDERAL PROGRAMS

Fiscal 1973 Agency funding for Air Programs is given in Table 3-1. Since most programs are organized along functional rather than along pollutant lines, it is not in general possible to allocate costs among the various pollutants.

In addition to expenditures for administration of governmental programs, the Federal government also incurs expenditures to abate emissions from Federally owned and/or operated facilities. Estimated hardware expenditures required to abate such emissions from existing facilities in the period beginning with FY 1974 and beyond are presented in Table 3-2.

III. STATE AND LOCAL PROGRAMS

The Act reaffirms the original jurisdiction of state and local governments over matters pertaining to protection of the quality of the air resource. To aid these units of government in effective prosecution of their responsibilities, EPA maintains ton regional offices covering the ten census regions and devotes by far the largest portion of the budget for air programs to control non-federal agency development and maintenance. Table 3-3 summarizes actual and projected financial support for air pollution control by state and local governments.

TABLE 3-1: Federal Air Pollution Control Estimates
FY 1973-1974 (In Millions of Dollars)

	1973	1974*
Research and development	69.1	57.1
Process and effects	30.9	29.8
Control technology	38.2	27.3
Abatement and control	85.0	79.8
Mobile sources	9.2	9.8
Stationary sources	5.9	6.3
Ambient trend monitoring	2.6	1.0
Technical assistance	13.1	9.1
Academic training	3.6	2.1
Air control agcy	50.6	51.5
Enforcement	4.2	8.7
Total	158.3	145.6

*Requested

TABLE 3-2: Projected Hardware Costs-Federal Facilities
(Millions of current dollars)

Department of Defense	$141.8
Atomic Energy Commision	.2
Department of Agriculture	3.0
Tennessee Valley Authority	38.1
Department of Transportation	.8
All Agencies	$183.9

Source: Office of Federal Liaison, Office of Air and Water Programs.

TABLE 3-3: EPA Grants For State And Local Control Agency Programs

	1972 Actual	1973 Estimated [1]	1974 Estimated [1]
State or Territory	Air	Air	Air
Alabama	527,324	709,427	861,100
Alaska	69,775	152,518	142,090
Arizona	207,049	512,614	563,400
Arkansas	208,527	280,295	407,000
California	3,690,260	3,893,615	3,769,990
Colorado	900,784	576,524	501,200
Connecticut	1,335,796	1,014,406	839,400
Delaware	189	260,054	212,200
District of Columbia	225,000	173,088	214,600
Florida	885,741	1,363,097	1,186,600
Georgia	630,218	684,100	1,085,400
Hawaii	96,445	157,395	101,200
Idaho	81,687	141,074	271,200
Illinois	2,423,520	2,830,000	2,640,000
Indiana	826,034	1,109,927	1,738,480
Iowa	559,243	498,841	687,600
Kansas	335,761	470,228	562,324
Kentucky	159,028	1,016,034	766,660
Louisiana	175,000	349,959	807,200
Maine	---	245,349	315,000
Maryland	987,000	852,115	850,800
Massachusetts	794,385	1,247,799	1,375,400
Michigan	1,613,520	2,010,073	1,853,600
Minnesota	365,669	700,097	873,600
Mississippi	421,724	477,699	590,430
Missouri	717,574	1,123,344	956,670
Montana	231,460	237,022	222,300
Nebraska	231,929	304,422	274,960
Nevada	245,702	248,532	248,200
New Hampshire	185,409	227,609	238,500
New Jersey	2,118,844	2,583,130	1,734,000
New Mexico	706,440	302,543	328,300
New York	3,967,790	4,232,424	3,755,800
North Carolina	1,489,069	1,050,998	1,154,400
North Dakota	45,000	62,207	89,600

TABLE 3-3: Continued

State or Territory	1972 Actual Air	1973 Estimated [1] Air	1974 Estimated [1] Air
Ohio	1,798,153	2,450,000	2,644,390
Oklahoma................	484,906	481,408	471,600
Oregon..................	486,828	667,492	532,300
Pennsylvania............	2,080,700	3,645,052	3,259,890
Rhode Island............	133,899	197,117	269,000
South Carolina..........	111,783	708,247	719,600
South Dakota	32,025	86,943	137,870
Tennessee...............	703,614	1,157,469	910,800
Texas	2,603,299	2,789,526	2,398,800
Utah....................	---	216,945	319,600
Vermont.................	224,426	173,669	98,800
Virginia................	1,062,000	618,516	1,007,400
Washington	1,129,910	1,194,024	1,003,050
West Virginia...........	317,620	322,693	500,700
Wisconsin	965,448	900,000	1,039,200
Wyoming.................	68,133	102,667	59,900
American Samoa..........	---	33,210	13,800
Guam	54,774	54,990	51,470
Puerto Rico.............	464,417	512,261	489,800
Virgin Islands..........	100,043	89,212	71,200
Total...........	$40,280,874	$48,500,000	$48,219,374

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[1] Dollar amounts are estimates of the actual amounts that may be awarded States during FY 1973. Estimates include funds to support the program that provides Federal employees to the States on a temporary basis.

CHAPTER 4. MOBILE SOURCE CONTROL COSTS*

I. INTRODUCTION

Transportation sources, a majority of which are motor vehicles for highway use, contribute heavily to air pollution. Regulations to control vehicular emissions distinguish two principal types of vehicles: 1) light duty, which are those vehicles designed primarily to carry 12 or fewer persons, and 2) heavy-duty vehicles, over 6000 pounds gross weight and designed primarily to transport property or carry more than 12 persons. EPA has established emission limitations for all new motor vehicles and engines, both light and heavy duty (Federal Register, Vol. 37, No. 221, November 15, 1972. Light duty trucks and multipurpose vehicles were included with light duty vehicles, until excluded by the Court of Appeals decision of February 10, 1973 and the Administrator's decision on April 11, 1973.) Table 4-1 summarizes the requirements for light-duty vehicles.

Table 4-1. Federal Emission-Control Requirements for Light-Duty Vehicles

Model Year	Pre 1968†		1968	1970	1971	1972	1973	1975	1976
Test Procedure	FTP	CVS-C	FTP	FTP	FTP	CVS-C	CVS-C	CVS-CH	CVS-CH
Emissions, grams/mile									
Hydrocarbons	10	17	3.4	2.2	2.2	3.4	3.4	0.41*	0.41
Carbon Monoxide	77	125	35.0	23.0	23.0	39.0	39.0	3.4 *	3.4
Nitrogen Oxides	4-6	6	NR	NR	NR	NR	3.0	3.1	0.4**
Evaporative losses grams/test	40	40	NR	NR	6.0	2.0	2.0	2.0	2.0

NR - No Requirement

† Uncontrolled vehicle except for crankcase blowby control.

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*On April 11, 1973, 1975 standards for hydrocarbon and carbon monoxide emissions by light-duty vehicles were suspended. Interim requirements were set at 0.9 grams per mile of HC emissions and 9 grams per mile of CO emissions for the state of California and at 1.5 grams per mile and 15 grams per mile, respectively, for the rest of the nation. 1976 standards remained unchanged at .41 and 3.5 grams per mile. The intent was to insure use of an oxidation catalyst on all 1975 vehicles sold in California, thus gradually phasing into general usage such devices as would be required on all cars to meet the 1976 standards. These recent developments can be expected to reduce materially the costs presented in this report.

**At this time hearings are underway concerning manufacturer requests for a one year suspension of the 1976 NO_x standards.

Test Procedures Used to Measure Emissions

FTP	Federal Test Procedure - The driving cycle is the California seven-mode cycle repeated nine times. Pollutant concentrations in the exhaust are analyzed continuously throughout the 16-minute test. Concentrations in each mode are multiplied by weighting factors to give grams/mile. This is not a true mass emissions measurement.
CVS-C	Constant Volume Sampling Procedure - This is a cold start mass emissions test. The vehicle stands at constant temperature for 12 hours at 70 degrees F before engine startup. The driving cycle is a 23-minute, 7.5-mile non-repetitive pattern. A constant fraction of the exhaust flow is collected in a bag, and concentration measurements at the end of the test give true mass emissions in grams/mile.
CVS-CH	Constant Volume Sampling Procedure - This is a cold-hot start weighted mass emissions test. The vehicle stands at constant temperature for 12 hours at 70 degrees F before engine startup. The driving cycle is the 23-minute pattern used in CVS-C. After a ten-minute shutdown, the engine is restarted and the first 505 seconds of the driving cycle repeated. A constant fraction of the exhaust flow is collected: the first 505 seconds in a "cold transient bag"; the next 864 seconds in a "stabilized bag"; and the repeat 505 seconds in a "hot transient bag." Emissions in cold and hot transient bags are weighted 0.43 to 0.57, respectively, and added to emissions in stabilized bag to give true mass emissions.

II. FUEL MODIFICATIONS

A. Regulations

Regulations have been promulgated to guarantee the general availability of one grade of lead-free fuel to protect potential post 1974 emission control systems. "Lead-free" grade gasoline, defined by the regulations as containing a maximum of 0.05 grams of lead per gallon, should be generally available by the summer of 1974. The use of phosphorus additives in lead-free gasoline is also restricted. EPA has proposed other regulations to diminish the lead content of leaded "regular" and "premium" grades of gasoline.

B. Cost Estimate of Fuel Modifications

By 1980, refineries will have to process an additional 1.2 million barrels of crude oil per day to compensate for lead removal and fuel penalties of pollution devices. With construction costs of $1700 per barrel refined per day, the investment will be over $2 billion.

If the petroleum industry passes all costs of the lead regulations to the consumer, net cost will be the sum of the increased cost of raw stocks, the operating and capital costs at the refinery, and the cost of changes in the distribution system, less the decreased maintenance costs for a car using lead-free fuels.

Increased fuel consumption due to emission controls will present a significant cost. Highway statistics through 1970 indicate a steady rise in the amount of gasoline used by a motor vehicle, as can be expected with increased use of optional equipment, increased safety equipment, and increased per-vehicle mileage. This trend indicates that in 1978, the estimated 40 million passenger cars in operation will use about 860 gallons per year for a total consumption of 95 billion gallons. Superimposed on this trend, in the current decade, will be an additional usage due to the fuel penalty of pollution control devices. The 1978 gasoline consumption of the estimated 11.0 million 1975 vehicle in operation may be 1 to 2 percent over that of 1973 vehicles. The estimated 33 million 1976-1978 cars in operation are expected to use 10 percent more fuel than 1973 vehicles. The increase of three billion gallons will cost about $1.19 billion.

In 1978, about half the gasoline sold will be lead-free and cost an additional one cent per gallon for a total increase of $0.49 billion.

The combined operating cost increase for these motor vehicles in 1978 is thus $1.68 billion, or about 4% of the total amount spent on gasoline.

III. EMISSION CONTROL APPARATUS

A. Configuration

The most likely 1975 emission control configuration for conventional engines will consist of improved carburetion, a fast-closing choke, a more durable ignition system, a noble metal oxidizing catalyst, a quick-heat mainfold, proportional exhaust gas recirculation (PEGR), and a manifold air injection pump.

In addition, there are three alternative power systems considered capable of meeting the 1975 standards on a limited mass production basis: 1) the light-duty diesels produced by Daimler Benz of West Germany, and Opel of General Motors, 2) the Wankel (rotary) enginer produced by Toyo Kogyo of Japan, and 3) a pre-chamber stratified charge engine manufactured by Honda of Japan. The Wankel powered vehicle which successfully completed the durability test phase has a thermal reactor and no catalyst. The vehicle passed several 50,000-mile tests with emission levels below the 1975 standards. The company believes that between 50,000 and 70,000 vehicles per month could be produced; over 200,000 have been produced to date. The Honda Compound Vortex Controlled Combustion (CVCC) engine has successfully completed 50,000-mile durability tests with emission levels below the 1975 standards. Honda does not require a catalytic device nor thermal reactor to meet 1975 standards, and intends to sell 250,000 cars in the U.S. in that year. Although each manufacturer is expected to produce vehicles using these technologies, adoption on a large scale appears unlikely.

Other manufacturers are relying almost completely on the present type of gasoline fueled spark-ignition engine equipped with various combinations of emission control components to meet the 1975-1976 standards.

One approach is improvement of carburetors, chokes, and intake manifold designs. Some foreign manufacturers are seriously considering electronic fuel injection, though at this time it apparently offers no advantage over improved carburetor designs.

Manufacturers are also working on improved ignition systems which are more accurate, reliable, and controllable, allowing maximum use of ignition spark timing modifications for hydrocarbon and nitrogen oxides emissions control.

Some companies appear to be interested in further application of electronic ignition systems, which offer improved reliability with less maintenance than conventional systems and may be inherently less prone to tampering.

Most manufacturers expect to use exhaust gas recirculation as the primary nitrogen oxide control technique in 1975. However, it appears that the 1976 nitrogen oxide level can be achieved with the conventional internal combustion gasoline engine only by development of a satisfactory nitrogen oxide reducing catalyst.

Air injection into the exhaust manifolds will be required on most of the systems that the industry seems to be considering for controlling carbon monoxide and hydrocarbons. These systems may be somewhat more complicated than those used in the past, and may require more sophisticated controls.

Thermal reactors (employing no catalysts) which can help control carbon monoxide and hydrocarbon emissions are not likely to be used with piston engines as the sole emission control technique by any manufacturer, although elementary thermal reactors may well be employed in conjunction with catalysts to accelerate catalyst bed warm-up.

Oxidation catalysts for control of carbon monoxide and hydrocarbons are almost universally planned by industry; however, achieving adequate catalyst life is still a major problem. At this writing, all auto manufacturers in the United States are favoring the noble metal type catalyst.

In summary, most of the manufacturers will be using integrated combinations of some or all of the above systems, which might include the following:

1. Engine modifications based on carburetion, intake manifold, and ignition system improvements (to control HC, CO, NO_x).
2. Proportional exhaust gas recirculation (NO_x).
3. Air injection (CO, HC).
4. Oxidation catalysts and integrated over temperature protection device (CO, HC).

A typical 1976 system, though less definite, may incorporate the above components, plus:

1. A reduction catalyst (as yet undeveloped).
2. More sophisticated air injection system.
3. More sophisticated carburetion.

B. Cost Estimates of Emissions Controls

Based on several recent reports and the monitoring of industry progress, the additional list price of emission control configurations for 1975 model light duty vehicles could range from about $150 upward over the 1974 model list prices.

The National Academy of Sciences estimates the additional list price to be about $175 for a 1975 configuration consisting of the components given in Table 4-2.

Recent improvements in auto emission controls may make some of these components unnecessary and lower the price of others. Normal dealer reductions in new-car list prices may effectively lower these additional costs as well. It is likely therefore, that the additional list price of a typical 1975 emission-control configuration for a six-cylinder engine light-duty vehicle will be less than $175 and may not exceed $150. For a V-8 model with two catalysts, the additional price may be as much as $200.

Present information also suggests that a 1976 emission control configuration may differ from a 1975 system only in that the EGR is replaced by a NO_x reduction catalyst. This catalyst will probably be comparable to the oxidation catalyst in cost. However, it is possible that additional body revisions and other changes may also be required. On this basis, a typical 1976 emission control configuration may have a net additional list price of $240 over 1973-1974 model prices.

The use of an emission control averaging $185 in model year 1975 motor vehicles and an emission control averaging $240 in later model years represents an investment of $12.5 billion in 1978. This is the bulk of the emission control investment for mobile sources listed in Table 1-3; the remainder is the additional investment by refineries in the production of unleaded fuel, as discussed in Section II-B of this chapter.

IV. OPERATING AND MAINTENANCE COSTS

Model year 1975 and 1976 vehicles will probably need more maintenance than uncontrolled cars to perform with low emissions. For example, EGR valves will need to be cleaned or changed, and catalysts may need to be replaced. In addition, they may require more fuel because of the pollution control devices. For a 1975 model car, the annual cost of operation and maintenance, including EGR maintenance, above that for a pre-1968 (uncontrolled) model vehicle, is estimated at $51.00 with catalyst changes and at $43.00 without changes. The annual cost of operation and maintenance for 1976-1978 model cars is estimated at $98.00 with change of oxidation and reduction catalysts, and $84,00 without changes.

Included in these figures is an expected reduction of maintenance costs due to the use of non-leaded fuel. Increased life of muffler systems and spark plugs will result in savings of 0.095 cents per mile; however, this will be partly offset by costs of hardened valve seats. The calculated net

Table 4-2. Estimated List Prices of 1975 Emission Control Components

Model Year	Configuration	Value Added	Tooling Amort.	Dealer Margin	Profit	List Price
1975	**Proportional EGR (accel-decel)	20.07	-	6.95	3.00	30.02
	New Design Carburetor with Altitude Compensation	7.52	2.00	3.30	1.43	14.25
	Hot Spot Intake Manifold	2.87	.30	1.10	.48	4.75
	Electric Choke (element)	2.67	.50	1.10	.48	4.75
	Electronic Distributor (pointless)	4.35	2.00	2.20	.95	9.50
	New Timing Control	1.40	.50	.66	.29	2.85
	Catalytic-Oxidizing-Converter	18.86	4.00	7.92	3.42	34.20
	Pellet Charge 6# @ $2.00/lb	12.00	1.72	4.75	2.05	20.52
	Cooling System Changes	1.17	.10	.44	.19	1.90
	Underhood Temp. Materials	.63	--	.22	.10	.95
	Body Revisions Welding Presses	.67	.60	.44	.19	1.90
	Assembly Line Changes	.13	.50	.22	.10	.95
	End of Line Test Go-No Go	1.85	.05	.66	.29	2.85
	Quality Emission Test	1.22	.05	.44	.19	1.90
	Air Injection System	27.16	1.30	10.03	4.33	43.32
	** EGR = Exhaust Gas Recirculation				Total 1975	$174.61

savings is $9.50 per year for 1975 model cars and 1976 cars, both using non-leaded gasoline. There is an annual increase in the cost of gasoline of $10 per motor vehicle due to the use of unleaded gasoline for catalyst-equipped vehicles.

Table 4-3 summarizes the total additional list prices, operation, and maintenance costs of 1975 and 1976 model light-duty vehicles due to air pollution controls. Total lifetime costs are given both with and without catalyst replacement.

V. BENEFITS FROM MEETING THE 1975-1976 STANDARDS

The national CO, HC, and NO_x emissions from light-duty vehicles in 1978 both with and without the 1975-1976 standards mandated under Section 202(b) of the Act are

CO: 52 million tons with control or 74 million tons without;
HC: 6 million tons with control or 8 million tons without;
NO_x: 3.1 million tons with control or 4.6 million tons without the 1975-76 standards for emission control.

As older cars with less or no emission control are retired from use, the reduction in pollution due to emission controls can be expected to become more significant.

Table 4-3. Estimated Maximum Additional Prices of 1975 and 1976 Emission Control Configurations Over 1970 Model Prices (1972 Dollars)

		Hardware[a]	Operation (per year)	Maintenance (per year)	One catalyst change [d]	Total Lifetime Cost (10 Year)	
						Without catalyst Replacement	With catalyst Replacement
1975	6-cylinder	$220	$ 8[b]	$6	$ 50	$360	$410
	8-cylinder	$270	$10[b]	$6	$ 75	$430	$525
1976	6-cylinder	$260	$50[c]	$6	$ 90	$820	$910
	8-cylinder	$350	$80[c]	$6	$155	$1,210	$1,365

[a] List prices.

[b] Assumes no fuel penalty, but increased cost of lead-free gasoline @ 1¢/gal.

[c] Assumes 15 percent fuel penalty and a gasoline price of $0.40/gallon plus cost of lead-free gasoline @ 1¢/gal.

[d] All costs for catalyst changes represent upper limits because: (a) monoliths were considered rather than pellets, (b) costs were taken to be maximal, (c) not all cars will require a catalyst change during 50,000 miles, and (d) catalyst material was taken to be platinum and palladium. These costs are spread over an assumed 100,000 miles, 10 year lifetime.

CHAPTER 5. INDUSTRIAL SOURCE CONTROL COSTS

I. INTRODUCTION AND SUMMARY

A. Selection of Industrial Sources

The sources of airborne emissions may be grouped into three major divisions: mobile sources used for transportation, large stationary sources where fossil fuel is consumed in the generation of electricity, and a miscellany of stationary industrial and agricultural sources. Each of these three major divisions is currently responsible for a roughly equal portion of current airborne emissions.

Costs of control were presented in chapter 1, with investments accumulated from 1970, the base year, through fiscal 1978. Since investments projected for the next five years (1974-1978) are of interest, these are presented in this chapter for each industry reviewed. The difference between these investments and those presented in Table 1-3 represents, of course, our estimates of investments made by June, 1973. Annual costs in this chapter reflect investments since 1970.

The list of sources analyzed is given in Table 5-1. Their number has been expanded to 46 from the 20 industries reviewed in the last annual report. Still, some activities that might seem to merit analysis may seem missing from the table. For some absences, the lack of information and of agreement on effective control strategy are to be held responsible. The painting industry, building, and road construction are in this category.

Some additions to the list are a result of New Source Performance Standards to be promulgated in 1973. As discussed in section 1B, the Standards have identified certain industrial operations in which it will be mandatory to control to a specified limit the emissions from units being constructed or modified after August 17, 1971. These now include steam generators fired by fossil fuels, incinerators, Portland cement plants, nitric acid production plants, and sulfuric acid production plants. In addition, standards have been proposed for asphalt concrete plants, petroleum refineries, petroleum and gasoline storage vessels, brass and bronze refineries, iron and steel mills, sewage sludge incinerators, and secondary smelters of lead. These standards were presented in Chapter 1.

B. Emission Estimates

For each industrial category of source, two sets of emission levels have been calculated: the level of emission of each pollutant with pollution

TABLE 5-1. Listing of Industrial Sources of Air Pollution

Burning and Incineration Group:
- Solid waste disposal
- Municipal incinerators
- Structural fires
- Forest fires, both controlled and accidental
- Agricultural burning
- Coal refuse burning
- Sludge incinerators for sewage

Metals Industries Group:
- Iron and steel manufacture
- Gray iron foundries
- New basic-oxygen furnaces for steel manufacture
- Ferroalloys
- Primary aluminum
- Primary copper
- Primary zinc
- Primary lead
- Primary mercury
- Primary beryllium
- Brass and bronze
- Mercury cell chlor-alkali
- Secondary aluminum
- Secondary zinc
- Secondary lead
- Secondary beryllium

Fuel Industries Group:
- Petroleum refineries
- Catalyst regeneration
- Petroleum products storage
- Gasoline and crude oil storage
- Coal cleaning
- Natural gas production
- Fuel gas burning
- Commercial heating
- Residential heating
- Drycleaning

Biochemicals Industries:
- Grain milling and handling
- Forest products
- Carbon black
- Kraft pulp

TABLE 5-1. Listing of Industrial Sources of Air Pollution--Continued

Quarrying and Construction:
- Crushed stone, sand, gravel
- Limestone crushing
- Cement
- Asbestos mining and milling
- Asbestos fireproofing and insulation
- Asbestos products
- Asphalt

Chemicals:
- Lime manufacture
- Sulfuric acid
- Nitric acid
- Phosphate fertilizer

control equal to that exercised prior to the Clean Air Act of 1970, and with control exercised in accordance with standards set under the provisions of that Act. These standards are provided in the State Implementation Regulations to achieve ambient air quality levels for the six criteria pollutants identified by the Administrator, New Source Performance Standards issued by the Administrator, and Hazardous Materials Emissions Standards also issued by the Administrator.

Emission levels are proportional to industrial output, provided emission control practice is unaltered. In addition to industry growth, trends in production methods are of importance. The steel industry, for example, exhibits an internal trend whereby open hearth production is decreasing, while production by the basic oxygen process and electric arc production are increasing. Available data on shifting percentages of production, as in the steel industry, were included in the analysis when the different modes of production yield different emission levels.

The magnitude of industrial output for each industry studied was projected through the 1974-1978 period, based on 1970 output and growth rate. The levels of emission in 1978, assuming no additional control, are given in Table 5-2 for each industrial source. Other emissions, such as sulfuric acid mist from sulfuric acid plants, omitted from this table, are presented in the individual discussion of the industry.

C. Control Analysis and Costing

The estimated annual costs of industrial air pollution control expressed in constant 1970 dollars, are included in Table 1-3. The figures present annual costs for each industry in 1978 and include interest on capital equipment, depreciation of equipment, and costs of operation and maintenance. Costs of monitoring the emissions that pass through the control devices have

TABLE 5-2. Airborne Emissions in 1978 With Current Control Practices (thousands of tons)

Industry	Part	SO_x	HC	NO_x	CO
Solid Waste disposal	2981	-	7283	-	5321
Municipal incinerators	60	-	-	-	-
Structural fires	49	0.4	57	5.7	186
Forest fires	1890	17	444	1220	5554
Agricultural fires	2400	-	2800	300	13800
Coal refuse fires	538	177	322	67	1610
Sludge incinerators	12	-	-	-	-
Iron and steel	690	-	-	-	4092
Coke	153	437	183	1.7	55
Gray iron	61	-	-	-	586
Basic oxygen	2.2	-	-	-	-
Ferroalloys	111	-	-	-	-
Primary Al	75	-	-	-	-
Primary Cu	79	4511	-	-	-
Primary Zn	22	140	-	-	-
Primary Pb	29	430	-	-	-
Primary Hg	15	-	-	-	-
Primary	-	-	-	-	--
Brass and bronze	13	-	-	-	-
Mercury chlor-alkali	.15	-	-	-	-
Secondary Al	0.97	-	-	-	-
Secondary Zn	6.7	-	-	-	-
Secondary Pb	17	-	-	-	-
Secondary Be	-	-	-	-	-
Petroleum refineries	218	4403	169	-	10445
Catalyst regenerators	7	-	-	-	45
Refinery tanks	-	-	1361	-	-
Gasoline tanks	-	-	682	-	-
Coal cleaning	71	-	-	-	-
Fuel gas heat	-	276	-	-	-
Natural gas	-	540	-	-	-
Commercial heat	6727	7398	-	1853	-
Residential heat	140	376	-	216	-
Drycleaning	-	-	15.5	-	-
Grain elevators	1306	-	-	-	-
Grain milling	233	-	-	-	-
Forest products	84.5	0.2	23	2.1	275
Carbon black	237	-	-	-	-
Kraft pulp	960	-	-	-	-
Stone, sand	2935	-	-	-	-
Limestone	390	-	-	-	-

TABLE 5-2. Airborne Emissions in 1978 With Current Control Practices--Continued (thousands of tons)

Industry	Part	SO_x	HC	NO_x	CO
Cement	432	-	-	-	-
Asbestos milling	4.3	-	-	-	-
Asbestos construction	15	-	-	-	-
Asbestos products	688	-	-	-	-
Asphalt	2184	-	-	-	-
Lime	687	-	-	-	-
Sulfuric acid	-	1857	-	-	-
Nitric acid	-	-	-	115	-
Phosphate fertilizer	348	-	-	-	-

not been included in the annual cost figures in the table. Costs for equipment presently installed are also omitted from this table.

For each industry, the total cost of air pollution control equipment installed between June 1974 and July 1978 is also presented in the table. These costs include that of the equipment, transportation, site preparation, and installation.

D. Pollution Level with Control

Future airborne industrial emissions levels will be affected by the growth of the industry in question, together with the control achieved over the process emissions.

Industrial growth can be extrapolated with a fair degree of confidence from trends in the past five years, whenever technological innovations are not involved. Where innovation has occurred, growth trends must be analyzed more carefully and some uncertainty will still exist. However, for the near term, this uncertainty is not a major problem. To take an example, a process emitting 1000 tons of pollution in 1972 and growing at a rate of 3 percent would in 1978 emit 1190 tons. If we had erred badly, and estimated the growth rate to be 5 percent, the 1978 emission forecast would be only 150 tons in error. In those industries where new source performance standards have been set up at significantly lower emission levels than existing sources, the contribution of growth to total emissions becomes less significant.

Present U.S. philosophy is not to reduce the industrial base and thereby reduce living standards to achieve clean air, but to apply controls to the industrial processes that have been identified as significant polluters. To this end, assistance in the form of long-term, low-interest loans for pollution control equipment is available when hardship can be demonstrated. The laws that regulate the amounts of industrial airborne emissions are summarized in

Chapter 1. In this chapter, it is assumed that in 1978 industry on the average will meet these regulations, perhaps with some plants achieving even lower levels of emission. With this working assumption, we may calculate the emission levels on an industry-wide basis, regardless of control device used to achieve this legal emission level.

The emission levels in 1978, with control, are presented on an industry-by-industry basis in Table 5-3. As with Table 5-2, only the principal five pollutants are presented.

TABLE 5-3. Maximum Airborne Emissions in 1978 with Control (thousands of tons)

Industry	Part	SO_x	HC	NO_x	CO
Solid waste disposal	205	-	967	-	655
Municipal incinerators	6	-	-	-	-
Structural fires*					
Forest fires*					
Agricultural fires*					
Coal refuse fires*					
Sludge incinerators	0.3	-	-	-	-
Iron and steel	46	-	-	-	4092
Coke*					
Gray iron	12	-	-	-	412
Basic oxygen	0.8	-	-	-	-
Ferroalloys	1.8	-	-	-	-
Primary Al	2.8	-	-	-	-
Primary Cu	3.6	826	-	-	-
Primary Zn	4	94	-	-	-
Primary Pb	1.8	186	-	-	-
Primary Hg	1	-	-	-	-
Primary Be	-	-	-	-	-
Brass and bronze	0.4	-	-	-	-
Mercury chlor-alkali	.02	-	-	-	-
Secondary Al	0.9	-	-	-	-
Secondary Zn	0.2	-	-	-	-
Secondary Pb	0.4	-	-	-	-
Secondary Be	-	-	-	-	-
Petroleum refineries	89	97	8	-	3292
Catalyst regenerators	1.8	-	-	-	45
Refinery tanks	-	-	575	-	-
Gasoline tanks	-	-	262	-	-
Coal cleaning	26	-	-	-	-
Fuel gas heat	-	27	-	-	-
Natural gas	-	22	-	-	-
Commercial heat	1076	1258	-	1056	-

TABLE 5-3. Maximum Airborne Emissions in 1978 with Control--Continued
(thousands of tons)

Industry	Part	SO_x	HC	NO_x	CO
Residential heat*					
Drycleaning	-	-	14	-	-
Grain elevators	23	-	-	-	-
Grain milling	4.6	-	-	-	-
Forest products	17	0.2	23	2.1	39
Carbon black*					
Kraft pulp	80	-	-	-	-
Rendering					
Stone, sand*					
Limestone*					
Cement	40	-	-	-	-
Asbestos milling	0.04	-	-	-	-
Asbestos construction	-	-	-	-	-
Asbestos products	116	-	-	-	-
Asphalt	607	-	-	-	-
Lime	85	-	-	-	-
Sulfuric acid	-	574	-	-	-
Nitric acid	-	-	-	12	-
Phosphate fertilizer	32	-	-	-	-

*No control feasible

II. BURNING AND INCINERATION

A. Group Description

Disposal of refuse is by burial, dumping, or combustion. The last of these alternatives, although it has many desirable features, is a significant source of air pollution.

At present, the two major methods of treating solid municipal waste are dumping and burning. Both incineration (the confined reduction of waste to ashes) and open burning result in significant airborne pollution but the exhaust from an enclosed incinerator can be vented through emission controls to reduce these emissions. Incineration is therefore to be preferred. Of course, no such choice is available when the burning is out of control, as with accidental fires!

GROUP 1: BURNING AND INCINERATION

Solid waste disposal
Municipal incinerators
Sludge incinerators
Structural fires
Forest fires
Agricultural burning
Coal refuse burning

The categories in this group whose emission control can be achieved most readily, and therefore the categories which receive the most attention, are the ones where the burning is conducted in closed incinerators. Uncontrolled incineration typically releases 10 to 30 pounds of particulates per ton of waste charged. State regulations require emission controls that reduce this to 2 to 4 pounds per ton. Specific regulations are given in Table 5-4.

TABLE 5-4. Regulations Applicable to Incineration Sources
(lbs particulate/100 lbs refuse charged)

	Capacity, lb/hr							
	<200	>200	<2000	>2000	<4000	>4000	>15,000	ALL
Alabama								0.20[1]
Alaska[2]	0.29	0.19	0.09[3]					
Arizona[4]								0.22
Arkansas	0.29	0.19						
California[5]								
Colorado	0.15	0.09						
Connecticut								0.08[6]
Delaware			0.20	0.18	0.16[7]			
Dist. of Col.								0.03[8]
Florida						0.08[9]		
Georgia					0.10[10]	0.08[10]		
Hawaii								0.20
Idaho								0.20
Illinois			0.09[10]	0.08[3]			0.05[11]	
Indiana			0.39[12]	0.23[3]				
Iowa								0.20

TABLE 5-4. Regulations Applicable to Incineration Sources--Continued
(lbs particulate/100 lbs refuse charged)

	Capacity, lb/hr							
	<200	>200	<2000	>2000	<4000	>4000	>15,000	ALL
Kansas	0.29	0.19					0.09[13]	
Kentucky								0.19[14]
Louisiana								0.19
Maine					0.19	0.08		
Maryland[15]	0.29[16]	0.19[16]	0.09[10]	0.03[10]				
Massachusetts								0.09[17]
Michigan[18]								
Minnesota	0.30	0.20		0.10				
Mississippi								0.09
Missouri[19]	0.29	0.19						
Montana	0.29	0.19						
Nebraska			0.19	0.09				
Nevada[20]								
N. Hampshire	0.29	0.19						
New Jersey			0.19	0.09				
New Mexico[21]								
New York								0.50[22]
N. Carolina	0.20			0.02				
N. Dakota[23]								
Ohio	0.20[24]		0.10[24]					
Oklahoma								0.40
Oregon[25]	0.29	0.19						
Pennsylvania								0.09
Rhode Island			.15[26]	0.08[26]				
S. Carolina								([27])
S. Dakota								0.20
Tennessee			0.20[28]	0.10[28]				
Texas[5]							([29])	
Utah								0.10

TABLE 5-4. Regulations Applicable to Incineration Sources--Continued
(lbs particulate/100 lbs refuse charged)

	Capacity, lb/hr							
	<200	>200	<2000	>2000	<4000	>4000	>15,000	ALL
Vermont								0.10
Virginia								0.13
Washington								0.09[30]
W. Virginia	0.41	0.27					0.13	
Wisconsin[31]	0.17[32]				0.11	0.08		
Wyoming								0.20
Samoa					0.20	0.10		
Guam								0.20
Puerto Rico					0.40			0.20
Virgin Islands	0.29	0.19						

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[1] 0.40 lbs/100 lbs refuse for wood waste burners

[2] for new installations only; 40% capacity for existing installations (more than 3 minutes in any hour)

[3] for >1000 lbs/hr capacity

[4] 0.09 lbs/100 lbs refuse for Maricopa County

[5] no general regulation stated in the final plan

[6] for new sources only; 0.23 lbs/100 lbs refuse for existing sources

[7] for <3000 lbs/hr capacity; no regulation stated for >3000 lbs/hr capacity

[8] for new sources only/ 0.08 lbs/100 lbs refuse for existing sources

[9] for new sources only; after July 1, 1975 existing incinerators with charging rates of >4000 lbs/hr shall be restricted to emitting 0.09 lbs/100 lbs refuse

[10] for new incinerators; 0.19 lbs/100 lbs refuse for existing incinerators

[11] for >60,000 lbs/hr capacity

[12] for <1000 lbs/hr capacity

[13] for >20,000 lbs/hr capacity

[14] for all existing sources and for new sources 4000 lbs/hr capacity; 0.08 lbs/100 lbs refuse for new sources 4000 lbs/hr capacity

[15] These regulations are for the following AQCR's: Eastern Shore, Md.; Southern Md.; Central Md.; and Cumberland, Md.-Keyser, W. Va. The following regulations apply to the other two AQCR's: National Capital Interstate and Metropolitan Baltimore; 0.03 lbs/100 lbs refuse for all incinerators after July 1, 1973

TABLE 5-4. Footnotes continued

[16] for existing and modified incinerators only

[17] for all existing incinerators and for new commercial, industrial, and residencial incinerators; 0.05 lbs/100 lbs refuse for new municipal incinerators--these regulations apply to all 6 AQCR's

[18] for Michigan the following regulations apply:

	Rating in lbs/hr	lbs/1000 lbs gas
Residential apartments	0-200	0.65
Residential apartments	200 and over	0.30
Commercial & Industrial	0-400	0.65
Commercial & Industrial	400 and over	0.30
Municipal	All	0.30

[19] 0.19 lbs/100 lbs refuse for all incinerators in Kansas City

[20] cannot exceed 20% opacity for periods totaling one minute in any one hour

[21] state regulation not specified in final plan. Albuquerque regulation: 0.09 lbs/100 lbs refuse for existing incinerators; construction, use or operation of new incinerators is prohibited and after Jan. 1, 1976 use or operation of any incinerator is prohibited

[22] for existing incinerators except in New York City, Nassau and Westchester Counties; for new and modified incinerators:

0.3 lbs/100 lbs refuse for <1000 lbs/hr capacity
0.22 lbs/100 lbs refuse for 10,000 lbs/hr capacity
0.13 lbs/100 lbs refuse for 100,000 lbs/hr capacity

for all incinerators in New York City, Nassau, and Westchester Counties:

0.2 lbs/100 lbs refuse for <1000 lbs/hr capacity
0.15 lbs/100 lbs refuse for 10,000 lbs/hr capacity
0.08 lbs/100 lbs refuse for 100,000 lbs/hr capacity

[23] for <1000 lbs/hr refuse burning rate $E = 0.00515R^{0.90}$ and for >1000 lbs/hr refuse burning rate $E = 0.025R^{0.67}$ where E = allowable emission rate in lbs/hr and R = refuse burning rate in lbs/hr

[24] for <100 and >100 lbs/hr capacity

[25] State regulations for existing sources; 0.09 lbs/100 lbs refuse for new sources; Regulations for Mid-Willamette Valley and Lane Regional:

0.19 lbs/100 lbs refuse for existing sources
0.09 lbs/100 lbs refuse for new sources

Regulations for Columbia-Willamette: Depending on heat input rate

0.09-0.29 lbs/100 lbs refuse for existing sources
0.05-0.09 lbs/100 lbs refuse for new sources

TABLE 5-4. Footnotes continued

[26] for new incinerators; applies to existing incinerators 3 years after effective date of regulation

[27] 0.5 lbs/10^6 BTU of heat input for new installations and for all incinerators by 1974; 0.75 lbs/10^6 BTU of heat input for existing incinerators

[28] for new incinerators only; 0.6 lbs/100 lbs refuse for existing incinerators with <200 lbs/hr capacity; 0.4 lbs/100 lbs refuse for existing incinerators >200 lbs/hr capacity

[29] 85% control for >10,000 lbs/hr capacity

[30] for all incinerators after July 1, 1975; until then 0.19 lbs/100 lbs refuse for existing incinerators and 0.09 lbs/100 lbs refuse for new incinerators

[31] for new sources; 0.34 lbs/100 lbs refuse for existing sources <500 lbs/hr capacity and 0.27 lbs/100 lbs refuse for existing sources >500 lbs/hr capacity

[32] for <500 lbs/hr capacity

The trend, then, is to prohibit open burning where feasible, and to install emission controls on incinerators. This is recognized as only part of the answer. Reclamation of individual resources from trash is already standard procedure for many items, notably metals, in many municipal trash systems. Separation of trash into its ingredients and recycling more of these ingredients can be expected to become more desirable economically with time and experience.

Once the reclaimable materials are extracted, can the residue be incinerated for profit? Studies of this possibility are underway. Conceivably, the heat generated when waste is incinerated can be of use. Used as fuel to generate steam for an electric power station, waste could become an asset rather than a liability. A demonstration project, consuming 300 tons per day to generate electricity, is to be carried out soon.

While major attention is being given to these possibilities for solid waste presently being incinerated, waste that is presently being burned in the open should not be overlooked. Air pollution by open fires can be controlled. Wasteful burning of stubble and weeds is recognized as poor agricultural practice not only for the air pollution resulting, but for the loss of organic matter that could be turned under to improve the soil. Accidental fires of structures or woods can be prevented or limited. The group of sources of pollution that is characterized by open burning remains to be given serious attention from a pollution point of view.

B. Solid Waste

1. Growth and Cost Factors

The amount of solid waste increases with population growth; the per capita amount is also increasing. The following table demonstrates the expected increase in the number of pounds generated per person per day.

	1970	1973	1978
Collected	6.0	6.6	7.6
Uncollected	5.1	5.6	6.5
Total	11.1	12.2	14.1

Collection costs neglected, the cost of disposal of this waste varies from a low of about $1.50 per ton for dumping on worthless land, up to $20 per ton in an incinerator. Many incinerators operate in the range of $5 to $20 per ton, with $7 being a typical figure.

Emission control requires electrostatic precipitators, high efficiency wet scrubbers, or other devices to limit particulate, carbon monoxide, and hydrocarbon emissions. A high efficiency wet scrubber for a typical 215 ton/day rectangular furnace incinerator would cost about $210,000 installed. Including operation and maintenance, it would cost about $49,000 annually. If the incinerator without control had operated at a cost of seven dollars per ton of charge, the emission control would increase this by 0.9%.

The costs on a nation-wide basis of meeting emission standards total an investment in the next five years of $519 million and an annual cost by 1978 of $250 million. In the following sections, the control strategy and its effectiveness in reducing air pollution are given.

2. Control Strategy

To obtain an estimate of the cost of reducing air pollution by burning and incineration and an estimate of the effectiveness of the control, it was necessary to assume a strategy for future solid waste disposal.

The control strategy assumed is the following:

a. All open burning of municipal waste is discontinued by 1978. At present, 25% of total collected refuse is disposed of in this way.

b. New municipal incinerators are installed to dispose of 25% of waste previously burned in the open.

c. Sanitary landfills replace the remainder of 1970 open burning refuse disposal and 25% of existing small incinerators.

d. No new small incinerators are built.

e. Old incinerators in each State are controlled to levels specified by its State Implementation Plan.

f. New municipal incinerators are installed in 1974-1978 with control levels specified by the New Source Performance Standards.

g. Open burning of agricultural waste and other open fires remain uncontrolled.

3. Emission Factors

The airborne emissions due to disposal in a sanitary landfill are negligible. For a goal of clean air, this solution to the solid waste disposal problem is ideal but the lack of sites makes it not always attainable, especially for municipal waste. Combustion reduces the bulk of the waste with the environmental price of airborne emissions. In pounds of emission per ton of waste handled, the emission factor is given roughly by the following table:

Source	Particulates	Hydrocarbons	Carbon monoxide
Open burning	16	30	85
Municipal incinerator	30	1.5	35
Small incinerator	30	7.5	20

where "small" incinerators typically handle less than one or two tons of waste per hour. As was mentioned above, each State Implementation Plan requires that incinerators be fitted with exhaust gas treatment to reduce the particulate emissions to a lower value, the gaseous pollutant emissions can be expected to decrease with this treatment. Table 5-5 summarizes the State limits, together with the maximum size at which an incinerator may be treated as a small incinerator.

C. Sewage Sludge Incineration

About forty new incinerators, of 10 ton/day capacity, represents the annual increase in sewage sludge incinerators. To meet New Source Performance Standards, each can be supplied with a low energy venturi scrubber, at a cost of about $60,000. These reduce particulate emissions from 60 tons/year for an incinerator without control, to 1.4 tons/year. The projected five year investment to fiscal 1978 is $12 million, with an annual cost in 1978 of $2,340,000.

III. METALS INDUSTRIES

A. Overview

Metals are undoubtedly the touchstone of civilization, but the symbol of the metals industries has too often been a cluster of tall chimneys sending black smoke into the sky. The refining of metals from their ores in all cases

Table 5-5. Particulate Regulations for Solid Waste Incineration

State	Pounds/ton of refuse burned		"Small"/"Large" Tons/hour*
	"Small" Incinerators	"Large" Incinerators	
Alabama	4.0	4.0	-
Alaska	([1])	([1])	-
Arizona	4.4	4.4	-
Arkansas	5.8	3.8	0.1
California	1.8	1.8	-
Colorado	3.0	1.8	0.1
Connecticut	4.6	4.6	-
Delaware	4.0	4.0	-
District of Columbia	1.6	1.6	-
Florida	30.8	1.8	2.0
Georgia	3.8	3.8	-
Hawaii	4.0	4.0	-
Idaho	4.0	4.0	-
Illinois	1.6	1.0[2]	30.0[2]
Indiana	7.8	4.6	0.5
Iowa	4.0	4.0	-
Kansas	5.8	3.8[3]	0.1[3]
Kentucky	3.8	2.0	2.0
Louisiana	3.8	3.8	-
Maine	3.8	1.6	2.0
Maryland	5.8	3.8	0.1
Massachusetts	1.8	1.0	1.0
Michigan	7.2	3.4	0.2
Minnesota	5.8	3.8[4]	0.1[4]
Mississippi	1.8	1.8	-
Missouri	5.8	3.8	0.1
Montana	5.8	3.8	0.1
Nebraska	3.8	1.8	1.0
Nevada	([1])	([1])	([1])

Table 5-5. Continued

State	Pounds/ton of refuse burned		"Small"/"Large" Tons/hour*
	"Small" Incinerators	"Large" Incinerators	
New Hampshire	5.8	3.8	0.1
New Jersey	3.8	1.8	1.0
New Mexico	1.8	1.8	-
New York	10.0	10.0	-
North Carolina	4.0	4.0[5]	1.0[5]
North Dakota	([6])	([6])	-
Ohio	4.0	2.0	0.05
Oklahoma	8.0	8.0	-
Oregon	5.8	3.8	0.1
Pennsylvania	1.8	1.8	-
Rhode Island	3.0	1.6	1.0
South Carolina	6.8	6.8	-
South Dakota	4.0	4.0	-
Tennessee	12.0	8.0	0.1
Texas	30.0	30.0	-
Utah	4.5	4.5	-
Vermont	2.0	2.0	-
Virginia	3.6	3.8	-
Washington	1.8	1.8	-
West Virginia	8.2	5.4[7]	0.1[7]
Wisconsin	6.0	4.0	0.25
Wyoming	4.0	4.0	-
American Samoa	4.0	2.0	2.0
Canal Zone	4.0	4.0	-
Guam	8.0	4.0	2.0
Puerto Rico	5.8	3.8	0.1
Virgin Islands	5.8	3.8	0.1

[1] No regulation (no incinerators).

[2] 3.8 lb/ton of refuse burned for less than 1 ton per hour of capacity.

Table 5-5. Footnotes continued

[3] 1.8 lb/ton of refuse burned for >10 tons (hour of capacity).

[4] 1.8 lb/ton of refuse burned for greater than 1 ton per hour of capacity.

[5] 4.0 lb/hour for greater than 1 ton/hour of capacity.

[6] Pounds/ton of refuse burned = .00515 $(\text{pounds per hour})^{.9}$ for less than 1,000 lbs. per hour capacity.

Pounds/ton of refuse burned = $(\text{pounds per hour})^{.67}$/10 (pounds per hour) for greater than 1,000 pounds/hour.

[7] 2.6 pounds/ton of refuse for greater than 7.5 tons of refuse per hour.

*The maximum incinerator capacity for which the "small" incinerator allowable emission factor applies.

in all cases results in airborne particulates that must be controlled. When the metal itself is highly toxic, as with mercury and beryllium, its vapors are of great concern. When the ore contains large amounts of sulfur, sulfur oxide emissions must be controlled. To these concerns must be added concern for control of carbon monoxide and hydrocarbon emissions in the metals industries, where coal is used to refine the ore.

GROUP 2: METALS INDUSTRIES

Iron and steel
Gray iron foundries
New basic oxygen furnaces
Ferroalloys
Primary aluminum
Primary copper
Primary zinc
Primary lead
Primary mercury
Primary beryllium
Brass and bronze
Mercury cell chlor-alkali process
Secondary aluminum and zinc
Secondary lead
Secondary beryllium

To put these industries into perspective, it is worthwhile to note U.S. production figures for 1970. In that year,

131.5 million tons of steel ingots,
93.8 million tons of pig iron and ferroalloys,

4.0 million tons of aluminum,
1.7 million tons of copper from native ores,
0.96 million tons of zinc,
0.67 million tons of lead, and
0.31 million tons of brass and bronze were produced.

One sees that the iron and steel industries are the largest; perhaps this helps explain why the largest quantity of emissions for the group, shown in Table 5-2, is given by this industry.

B. Iron and Steel

1. Description

Steel production in the U.S. is highly concentrated, with more than 50% of production accounted for by four companies and an additional 25% by four more. However, when one considers the processes involved in transforming iron ore into fabricated iron or steel products, hundreds of companies are involved. These processes include coking, in which coal is reduced to coke in coke ovens; sintering, in which iron ore is beneficiated and prepared for charging into blast furnaces; smelting, in which pig iron is produced from iron ore, coke and limestone in blast furnaces; casting in iron foundries when steel is not desired for the final product; refining, in which iron ore is refined into steel (and alloyed if desired) in open hearth, basic oxygen, or electric furnaces; rolling, in which raw steel is shaped into blooms, billets, slabs and other basic shapes; finishing, in which basic shapes are rolled, drawn, coated, or otherwise treated to produce sheet, strip, tin plate, pipe, wire, and other products for use in manufacturing; and fabrication of finished products.

Blast furnaces are always well controlled to prevent the emissions of particulates, while the gaseous emissions are fully utilized in the production of process heat. At present, very little is known about the emissions or present control patterns for the scarfing machines that are used to clean the surface of billets before rolling. Control of coking operations at existing facilities, which constitute significant sources of both particulate and gaseous emissions, does not appear to be either technologically or economically feasible. There does not appear to be adequate technology to significantly reduce particulate emissions during coal charging and coke pushing operations from byproduct coking. Required technology consists of sealed ovens and offgas collection of particulates vented to scrubbers, such as are installed on modern coke ovens. However, most older ovens are not structurally designed for this approach. Therefore, total replacement of many coking plants would be required. The steel industry expects technological developments in a few years to improve the coking process itself ("third generation" technology) which will require large amounts of new capital. This is a deterrent to investing heavily in modern facilities which will become obsolete within a few years. Cost estimates of $1 to $1.5 billion for control of current facilities have been mentioned by various sources, but these estimates are of questionable reliability. For these reasons, control cost for coking have not been included.

Very little recent growth has occurred in the steel industry. Industry changes will be dictated by technology during the next few years. A survey of available data indicates that for the period 1971-1978, six new basic oxygen process furnaces of approximately 250 tons/heat capacity will be built to provide additional capacity of 13 million tons of steel per year, and eight new electric arc furnaces, of about 84 tons/heat capacity, will be built to provide an additional capacity of 1.5 million tons. Against these additions, it is expected that 16 open-hearth furnaces of 250 tons/heat will close, removing 6 million tons of production, and 9 sintering plants of 4,000 tons/day capacity will also close, removing 11 million tons of production. The net result of these changes is a loss in steel making capacity of 2.5 million tons.

A similar lack of growth is evident in the iron fabrication industries. Iron foundries, which use pig iron, gray iron and scrap, show zero growth for the short term. Ferroalloy production, where iron is combined with manganese, chromium, silicon, or other elements to produce specific products, appears to be growing an an annual rate of 0.6 percent.

2. Emissions and Control Costs

Airborne emissions by the iron and steel industry are principally results of coke production, steelmaking, and casting operations. Particulate emissions are most obvious and are normally controlled where they originate from sources that are not too diffuse, such as blast furnaces. Sulfur oxides are of high priority. About 75% of all sulfur entering a plant is found in coke-oven gas and slag from blast furnaces. If the gas is used as a fuel, the sulfur is carried off as sulfur dioxide. When the slag is disposed of, it may give off hydrogen sulfide while weathering. Practical controls for these gaseous emissions are not available.

Particulate emission factors are given in the following table for the various processes.

Particulate Emissions in Steel Processing

Process	Lbs/ton of product
Open hearth	22
Basic oxygen	46
Electric arc	11
Sintering windbox	20
Sintering discharge	22

Because there is no currently ac[illegible] practice for control of emissions from coke ovens, the following levels [illegible]ission are expected annually:

153,000 tons of particulates

437,000 tons of sulfur dioxide
55,400 tons of carbon monoxide
183,000 tons of hydrocarbons
1,700 tons of nitrogen oxides
7,800 tons of ammonia

Blast furnace operation results typically in very little particulate emission. The hot gases from the furnace are stripped of dust and used as fuel. These gases contain very little sulfur.

Steelmaking emissions call for high-energy wet scrubbers, electrostatic precipitators, or fabric filters. The cost and size of the emission control system depends on plant size and pertinent State regulation. Regulations controlling particulate emissions are based on plant throughput, with smaller plants permitted larger quantities of emission per ton processed.

For new plants, New Source Performance Standards apply. These can be expected to require an investment of $1,327,000 between 1974 and 1978, and an annual cost of $497,000 in 1978. These figures are included in the industry costs given in Table 5-3. It is anticipated that four new furnaces will be affected by the New Source Performance Standards between 1974 and 1978.

To reduce emissions, a combustion hood and precipitator can be placed on two 250 ton/melt furnaces, manifolded together, at a cost of $663,000. The industry investment in fiscal years 1970-78 will total $494 million, with an annual cost in 1978 of some $179 million. This will result in a reduction of particulate emissions from new basic oxygen furnaces from 2190 tons to 882 tons in fiscal 1978.

3. Iron Foundries

Iron foundries produce castings, such as iron pipe, machine parts, and automobile parts, from gray iron, pig, and scrap. The industry employs four types of furnaces to melt iron for casting--electric arc, electric induction, reverberatory, and cupola furnaces. Cupolas currently account for over 85 percent of all castings, with electric arc and induction accounting for most of the remainder. Electric induction and reverberatory furnaces emit relatively small quantities of pollutants and require little or no air pollution control expenditures. Electric arc furnaces account for less than 5 percent of industry production.

Cupolas are vertical, cylindrical furnaces in which the heat for melting is provided by burning coke in direct contact with metal charge. Most foundry emissions result from this metal-melting operation. Particulates, in the form of dust and smoke, and carbon monoxide are the significant emissions from cupolas. Afterburners, to oxidize carbon monoxide emissions, and gas-cleaning equipment, such as wet scrubbers or fabric filters, can achieve compliance with stringent process weight regulations for particulates and a 95 percent removal rate for carbon monoxide. Cost of control is on the order of $300,000 investment for a high-energy wet scrubber, with $125,000 the annual cost in 1978. Without control, about 17 lbs of particulates and 145 lbs of carbon monoxide are emitted per ton of metal melted.

The iron foundry industry is expected to invest $579 million for particulate control, and $2.1 million for carbon monoxide control to meet ambient air standards. In 1978, these investments, with operation and maintenance costs, will result in annual costs of $163 million and $4.4 million respectively. Of this last figure, $3.9 million is attributed to operation of the carbon monoxide afterburners.

4. Ferroalloy Industry

The independent ferroalloy industry consistes of about 140 electric furnaces where iron is combined to form such ferroalloys as ferromanganese (FeMn), ferrochromium (FeCr) and ferrosilicon (FeSi). The numerous other ferroalloys are produced in relatively small quantities and quite often under well-controlled conditions. Ferroalloy production is expected to follow the growth pattern of the iron and steel industry.

The major pollutant from ferroalloy plant installations is particulates. The rate of particulate emissions from the United States ferroalloy industry in 1967 is estimated to have been 160,000 tons per year. It is estimated that this total consists of 1,000 tons from blast furnaces, 150,000 tons from electric submerged-core furnaces, and 9,000 tons from handling of materials.

An uncontrolled 30-Mw electric submerged-arc furnace producing ferromanganese, silicomanganese, or calcium carbide can release 800 to 2,000 pounds of particulate emissions each hour of operation. Well-controlled ESA furnaces producing ferromanganese, silicomanganese, and calcium carbide are totally enclosed. Fumes are collected and directed to venturi scrubbers, fabric filters or electrostatic precipitators; venturi scrubbers are the most common collection device. Average emissions (excluding tapping emissions) from well-controlled 30-Mw furnaces producing ferromanganese, silicomanganese, and calcium carbide vary from about 0.03 to 0.09 pound per hour (0.001 to 0.03 lb/Mw-hr.). The investment cost for this control for the next 5 years is estimated as $245 million and annual cost of $66 million in 1978.

C. Aluminum

1. Nature of Product and Process

Virtually all aluminum is produced from bauxite ore. The ore is processed to remove impurities and chemically combined with water, leaving alumina (aluminum oxide). Aluminum is commercially produced by passing an electric current through a molten bath of alumina dissolved in cryolite (Na_3AlF_6) which serves as the electrolyte. This is done in a large carbon-lined steel pot holding the alumina solution, with carbon anodes suspended from above and extending down into the solution. The carbon combines with the oxygen in the alumina, gradually consuming the anode. The aluminum gathers at the bottom of the pot and is periodically syphoned off. The pots are run continuously over long periods of time with alumina added as necessary to maintain the necessary solution and the anodes gradually lowered into the bath to maintain the required position.

Three types of pots are employed, distinguished by the type of anode and the location of the spikes through which the current is fed to the pot. Prebaked systems use anodes that are carbon blocks separately formed and baked before use. In the Soderberg system an unbaked carbon paste is fed into a casing in which it is baked by the heat of the process as it is lowered, with additional paste feeding in constantly from above. Two types of Soderberg pots are used: horizontal spike, with the spikes on the side of the pot, and vertical spike, with the spikes on the top.

The pots are operated in large cell rooms containing lines of up to 180 pots arranged in a row or loop to provide close spacing for economical electrical connections.

2. Emissions, Controls, and Cost of Control

Particulate emissions from the potlines in primary aluminum plants in 1967, with 73 percent control, were 31,800 tons. At the same level of controls, there would be 74,717 tons of particulates emitted by fiscal 1978.

The emission control systems required for even close approach to the applicable standard are very complex because of the extremely fine nature of the particulates and the large gas volumes which must be handled. Each pot must be hooded and vented to a primary collection system to capture as much of the emission as possible with minimum gas flow. The proportions of particulates captured by the best possible hooding systems are shown in Table 5-6 for each pot type. Also shown in the table are the overall control efficiencies attainable for each pot type. These provide an average control of 97.2 percent for the industry. To meet the applicable standard each plant should achieve an overall removal efficiency of approximately 98 percent. As the table shows, only newer prebaked plants will do so.

The type of pot in use determines what type of primary control system is required; these systems and the associated removal efficiencies, are listed in

TABLE 5-6. Particulate Emission Capture by Cell Hoods

Pot type	Emissions (lbs/ton)	Particulates captured by best available hooding (%)	Overall control efficiency attainable (%)*
New prebaked	55	95	98.2
Older prebaked	55	79	97.1
Vertical spike Soderberg	80	50	94.5
Horizontal spike Soderberg	140	80	97.2

* Only systems on new prebaked potlines are capable of meeting the process weight rate standard.

Table 5-7. For the remaining emissions, the pot room itself acts as a hood and is vented to a secondary control system. All pot rooms require use of cross flow packed bed wet scrubbers with appropriate water treatment, achieving a 90-percent removal of entrained particulates.

TABLE 5-7. Primary (Cell Hood) Emission Control Systems

Pot type	Control Systems	Removal Efficiency (%)
Prebaked	fluidized-bed dry scrubber	99
Vertical spike Soderburg	dry electrostatic precipitator followed by cross flow packed-bed wet scrubber*	99
Horizontal spike Soderburg	wet electrostatic precipitator followed by cross flow packed-bed wet scrubber*	99

* Scrubbing water must be treated for water pollution control

Costs of control for Soderberg pots are significantly higher, even at the lower overall efficiencies shown in Table 5-6, because the hooding is relatively inefficient. In addition, gaseous hydrocarbons from the anode slurry are driven off as the anode bakes during pot operation. These hydrocarbons must be flared to avoid fouling the emission control systems, thereby greatly increasing gas handling problems. These hydrocarbons also affect the fluorides in the gas stream; only fluorides recovered from prebaked pots are reused. Cost savings from reuse of these fluorides are included in the control costs presented below.

At the control levels indicated, it is estimated that particulate emissions from the primary aluminum industry would be 2,800 tons in fiscal 1978.

Required investment and annualized control costs have been estimated, by company, on the basis of projected fiscal 1978 capacity and summed for the industry as a whole. The required investment through fiscal 1978 is estimated to total $751.4 million, and the annual cost of control for that year is estimated to total $209.1 million.

Net annual control cost per ton of capacity, after allowance for recovery of valuable materials from the control devices, is lowest for firms using the prebaked process--vertical spike Soderberg cells cost 1.6 times as much per ton and horizontal spike cells cost 2.8 as much. Depending on the proportions of systems used, firms with some Soderberg cells will experience an average annual control cost ranging from 10 to 100 percent higher per ton of capacity than those required of firms using prebaked cells only.

D. Copper, Brass, and Bronze

1. Industry Description

There are three main stages in the production of primary copper: mining and milling, smelting, and refining. Copper ores are usually mined by open-pit methods and are concentrated in mills on or near the mine site. The concentrates are transported to smelters and processed to produce "blister" copper. There are seven smelters in Arizona, and about as many more in all the rest of the Western states, located close to mining areas. The final stage of production, refining the blister copper, is usually by electrolytic deposition. Refineries tend to be located where the fabricators are. An annual average growth of 2.2 percent in production of primary copper is anticipated for the next five years.

Secondary copper, produced from scrap, may or may not require smelting. Where the copper has been combined with other materials, the alloy is not refined but used as is. The secondary copper industry produces about 35 percent of copper products in the United States.

Almost all the copper alloys in use are brass where zinc is the additive, or bronze, where tin is the additive. Other metals are frequently added in these alloys to enhance specific properties. Brass and bronze are generally manufactured from copper-bearing scrap. There are about 183 brass and bronze plants, widely dispersed about the country. This industry is essentially stable, with a zero growth rate.

The scrap, after some preprocessing and sorting, is cleaned and charged into a furnace to be melted, smelted, refined, and alloyed as required. The most common type of furnace in use is the stationary reverberatory furnace. Batch processing is used; 10 to 100 tons are typically processed in 24 to 48 hours. For small batches, seldom exceeding 30 tons, cylindrical rotary furnaces are used. For special alloys in very small batches, crucible furnaces are used.

2. Emissions and Cost of Control

Sulfur dioxide is the primary pollutant emitted from the smelting of copper ore concentrates. Sources of emission are roasters, reverberatory furnaces, and converters. The emissions are characterized by heavy mass rates and relatively weak flue gas concentrations from reverberatory furnaces and uneven pulsating flows from converters. In addition, the flows are contaminated with small quantities of materials harmful to human health, such as arsenic, bismuth, cadmium, and mercury. These factors also make the collection of sulfur pollutants difficult and costly.

Generally, sulfur dioxide emissions from reverberatory furnaces and converters are uncontrolled. Control techniques depend on the size of the furnaces, gas flows, emission rates, plant condition, and degree of obsolescence of present smelters. (Average age of existing smelters is 40 years.) For some plants, reverberatory furnaces may have to be replaced with flash smelters; flue ventilation systems will have to undergo extensive modification, and converters may have to receive oxygen enrichment to produce gas volumes sufficiently small for less expensive control facilities. Overall control will rise from an average of 81 percent in 1970 to meet the regulations given in Table 5-8. Control techniques costed for this report take into account the costs of calcium sulfate and sulfuric acid recovery and modifications of dry precipitators and flue gas flows. Other production and process improvements are not included.

TABLE 5-8. Sulfur Oxide Regulations for Primary Copper Smelters

State	Regulation
Arizona	26.335 tons of SO_x/hr (state total)
Montana	3.52 tons of SO_x/hr
New Mexico	60% control
Nevada	60% control
Texas	43% control
Utah	14.7 tons of SO_x/hr
Washington	90% control

The investment required for primary copper smelters is $771 million. Annual costs are $178 million by fiscal 1978 with full implementation of controls. No credits were assumed for collected by-products.

The 1973 emission level of 4.02 million tons of sulfur dioxides will increase to 4.51 million tons in 1978 without new controls; full implementation will reduce the level to 826,000 tons. The 1973 emission level of particulates of 70,625 tons will increase to 78,846 tons in fiscal 1978 without net controls; full implementation of the abatement strategy for sulfur dioxides will reduce particulates to 3,625 tons.

The investment required for brass and bronze plants is $13.5 million. Annual costs are $2.67 million by fiscal 1978 with full implementation of controls for particulates. The model control system selected was fabric filters.

The 1973 emission level of 12,241 tons of particulates will remain the same in 1978 without new controls; full implementation of State Implementation Plans and New Source Performance Standards in this industry will reduce the level to 339 tons.

E. Lead and Zinc

Primary lead smelting is similar to zinc smelting in that the first treatment is sintering for separation of sulfur from the desired metal. The sintered product is lead oxide, which is reduced to lead in a blast furnace and further purified in a lead refining furnace.

Sulfur dioxide is the primary pollutant emitted from the smelting of lead and zinc ore concentrates. For lead smelters, sinter machines account for about 98 percent of total emissions. The gas volume flow is steady from the sinter machine and is of sufficient sulfur dioxide concentration (about 5 percent) to permit its recovery as sulfuric acid. As seen from Table 5-9, half of the United States lead smelters have acid recovery plants.

Investment required for the primary lead industry to apply the control techniques cited in the table is $24.4 million, and annual costs are estimated to be $6.06 million by fiscal 1978.

Zinc sulfide concentrates are roasted in Ropp, multiple-hearth, or other type roasters to separate the sulfur from zinc. In the roasting step, the zinc sulfide is converted to zinc oxide calcine. Sintering machines are then used to agglomerate the calcine material. Recycled dusts and other valuable materials are added to the sintering to produce the final zinc-bearing agglomerates. Metallic zinc is extracted by electrolytic deposition or by distillation in retorts or furnaces. Electrolytic deposition requires a preliminary step of leaching zinc calcine with sulfuric acid to form zinc sulfate for the electrolysis step.

TABLE 5-9. Primary Lead Plant Inventory, 1970

State	Number of plants	Capacity (Tons of charge)	Present acid plant (Yes, No)	Control technique applied 1/
Idaho	1	300,000	Yes	S,I
Missouri	3	600,000	Yes	A
		300,000	Yes	A
		180,000	No	A
Montana	1	420,000	No	A
Texas	1	420,000	No	A

1/ Control techniques applied:

A - Acid plant

S,I - Dimethylaniline scrubber plus intermittent operation.

The emissions of sulfur oxide from zinc smelters are basically from those plants that emit dilute off-gas from roasters and sinter machines. These gas streams usually contain about 0.5 to 1.0 percent in sulfur dioxide strength. Recovering sulfuric acid from such a diluted gas is costly. (Zinc plants that do recover sulfuric acid have concentrated sulfur dioxide gas streams.) Like the lead industry, dry collectors are not included in the cost estimates, and it is assumed that the limestone scrubbers used for removing sulfur dioxide emissions will also sufficiently remove particulates. Investment required for the zinc industry amounts to $21.1 million, and annual costs under full implementation are estimated to be $6.46 million by fiscal 1978.

The assumed controls should reduce the estimated fiscal 1978 emission level of 140,000 tons of sulfur dioxide to 93,500 tons. (Emissions for 1973 were 140,000 tons.) Particulates emitted in 1973 were 2,000 tons; the fiscal 1978 level will be reduced to 4,000 tons.

The secondary lead industry uses scrap lead, much of it from motor vehicle storage batteries. It involves nearly 150 companies and accounted for some 536 thousand tons of lead in 1970, or about 31.4 percent of United States consumption. Growth of this industry is expected to consist of two new 50-ton/day lead furnaces of various types in operation each year. From recent trends, blast furnaces will be selected twice as often as reverberatory furnaces. New source performance standards apply, and particulate emissions are to be controlled, probably by fabric filters.

The investment required for the secondary lead industry is $1.68 million. Annual costs are $687,000 by fiscal 1978 with these controls. The 1978 emissions without controls would be 906 tons of particulates; control reduces this to 75 tons.

F. Mercury

Without emission controls, the production of a seventy-six pound flask of mercury can result in about 1680 grams (3.7 lbs) emitted, half as mercury vapor and half as mercurous particulates. The proposed national standards for mercury will limit refinery emissions to five pounds a day. Controls to meet this standard will normally be required of plants with an output of over 700 flasks per year.

Recognition of the toxicity of mercury and mercury compounds is curtailing its use. In 1970, about 27,300 flasks were produced, with two-thirds of this in California alone. Annual production over the fiscal years 1973-1978 is expected to average about 8000 flasks. Without emission control, this would result in 14.8 tons of mercury emitted to the atmosphere in fiscal 1978. With an investment of $348,000 and annual costs of $56,000, this emission can be reduced to 1.1 tons.

G. Beryllium

There are only two firms producing beryllium metal. These firms produce the pure metal, metal sheets and shapes, and a wide range of other materials containing beryllium in five plants.

An engineering analysis of air pollution control for both these firms indicates that all potential sources of beryllium emissions are controlled within the limits of the control standards proposed. At the present time, over 90 percent of the pure beryllium metal produced is used in products made for the United States Government, particularly for the Department of Defense and the Atomic Energy Commission. These agencies have, for many years, required suppliers to comply with the guidelines proposed for the maximum allowable concentration of beryllium in ambient air. As a result, the major producers of beryllium products are familiar with the hazards involved and have been complying with the proposed standards.

Firms processing beryllium and beryllium compounds include firms forming and shaping metal, such as machine shops, foundries and forges, and makers of molds for plastic parts; firms alloying metals; and firms manufacturing ceramic products. Processes include melting, casting, forging, turning, shaping, grinding, rolling, slitting, stamping, cutting, and bending. Any nonferrous foundry, metal fabricating or machine shop has the capability of working beryllium or its alloys. Because of this and the wide range of applications, beryllium becomes widely dispersed and may lose its identity, making it very difficult to identify the firms and products of its ultimate use.

The two primary producers of beryllium metal also produce secondary beryllium products. An engineering analysis of air pollution control for these two firms indicates that beryllium emissions from their plants are within the limits of the proposed control standards. Similarly, an analysis of the five plants using beryllium oxide in making approximately 99 percent of the ceramic products containing beryllium indicates that present emissions are within the limits of the proposed control standards.

The proposed national emission standard for beryllium provides total emissions to the atmosphere shall not exceed 10 grams of beryllium in a 24-hour day or 0.01 microgram of beryllium per cubic meter of air averaged over a 30-day period, measured in accordance with a sampling network approved by the Administrator.

IV. FUELS INDUSTRIES

A. Overview

The products of the industries included in this section are distinguished by having carbon in their makeup. They are part of the organic world, having participated at some time in the cycle of life. With the fossil fuels, of course, this participation was in the distant past. Therefore, we place fuels industries into a subdivision of the group discussed herein, and the remainder of the industries lumped somewhat indiscriminately into a second subdivision.

All the products of the industries in this group contain carbon and are, to various degrees, storehouses of chemical energy. As such, they can be combustible and yield the pollutants carbon monoxide and volatile hydrocarbons.

Group 3a: FUELS INDUSTRIES

- Petroleum refineries
- Catalyst regeneration
- Petroleum products storage
- Gasoline and crude oil storage
- Coal cleaning
- Natural gas production
- Fuel gas burning
- Commercial heating
- Residential heating
- Drycleaning

Group 3b: BIOCHEMICALS INDUSTRIES

- Grain milling and handling
- Forest products
- Carbon black
- Kraft pulp process
- Rendering

B. Petroleum Refineries and Product Storage

There are about 130 firms, owning 250 refineries in the petroleum industry. This industry, storing hydrocrabons, refining and burning them, presents a major potential for air pollution. New Source Performance Standards have been promulgated for refineries and for storage depots; State Implementation of Clean Air requirements combine with these standards to call for a large control effort by the industry.

The industry is estimated to grow at a rate of 4 percent per year. In recent years, this growth has taken the form of expansion of existing operations. Three stages in the industry are singled out for emission control: catalytic cracking, petroleum and petroleum products storage, and burning. The emissions during the catalytic cracking process are shown in Table 5-10.

TABLE 5-10. Emissions per 1000 bbl of Petroleum Cracked

Process	Particulates	Hydrocarbons	CO
Fluid	76 lb	273 lb	8.5T
Thermofor or Houdriflow	23.5 lb	120 lb	2.6T

Refinery emissions of hydrocarbons from catalytic crackers and regenerators were estimated at 158,000 tons in 1973, at 20 percent control. Industry growth would increase this to 169,000 tons by fiscal 1978 if control practices remained unchanged. Use of carbon monoxide-hydrocarbon boilers on crackers could effect a 95 percent control level, reducing emissions to 8000 tons in fiscal 1978.

Sulfur dioxide emissions in refineries may occur from many sources including internal combustion engines for compressors, boilers, catalyst regenerators, acid plants, hydrogen sulfide incinerators, and sulfur plants.

Engines and boilers are commonly fueled by sulfur-bearing gases or liquids that cause scattered, relatively dilute, sulfur dioxide emissions. Catalyst regenerators have sulfur oxides in exit gas streams, depending on the sulfur content of the coke deposited on the catalyst. Spent alkylation acid (H_2SO_4) sludge may be shipped away for regeneration, but if it is regenerated at the refinery, the emissions of sulfur oxides should be similar to those for other nonsulfur-burning acid plants. Hydrogen sulfide (H_2S) incineration, at refineries producing H_2S not used for acid sludge regeneration or sulfur plant feed, is a large concentrated source of SO_2 emissions; when sulfur plants are used on the H_2S stream (in place of incineration), they are strong sources of SO_2 emissions.

The primary source of SO_2 in most refineries results from processing the H_2S-rich stream generated from various desulfurization and sweetening processes. The H_2S stream is most commonly produced in the regeneration of spent amine scrubbing liquors used to sweeten product, process, or exhaust streams. The stream may be incinerated, sent to a spent acid regeneration plant, or sent to a sulfur recovery plant. All three processes result in significant emissions of sulfur oxides. Incineration of hydrogen sulfide to sulfur dioxide is normally controlled by recovery as sulfuric acid; these and spent-acid plant emissions are included in Section P on sulfuric acid. Sulfur plants and their tail gas streams are considered below. The H_2S-rich stream is amenable to partial recovery by conventional Claus sulfur plants.

Hydrogen sulfide emissions in refineries are best controlled by use of sulfur recovery plants. The available data indicate that many of the refineries have sulfur plants and that overall these provided control of 37 percent of emissions. Thus, the plants emit 4,393,000 tons of sulfur oxides per year, and it is estimated that industry growth would increase this to 4,403,000 tons by fiscal 1978 with the same sulfur contents and level of control. Installation of sulfur plants and tail gas cleaners on all refineries could reduce the fiscal 1978 emissions of sulfur oxides from these sources to 97,000 tons per year. There are additional sulfur oxide emissions that result from operations involving the combustion of natural gas and/or fuel oils for process purposes. These are not generally amenable to control.

Regeneration of the catalysts used in catalytic cracking units results in emission of catalyst fines (particulates) and carbon monoxide. An estimated 140 pounds of particulates per thousand barrels of total feed are emitted from fluid catalytic cracking unit regenerators in the absence of air pollution control equipment, and an estimated 12.5 pounds per thousand barrels of total feed from thermofor and houdriflow unit regenerators. Installation of electrostatic precipitators provides the maximum control now available, and should easily meet the assumed process weight rate standard.

Carbon monoxide in the exit gas of regenerators has been controlled by carbon monoxide boilers in many refineries. The carbon monoxide boiler burns the carbon monoxide into carbon dioxide (and also burns hydrocarbon emissions from the catalytic cracking unit) and provides a substantial source of heat for process use in addition to controlling pollution. Installed in all the subject refineries, they would control all but a negligible amount of carbon monoxide and hydrocarbon emissions from the cracking process.

Nearly all bulk storage of petroleum or petroleum products consists of storage at the refinery of crude oil and gasoline, and storage at bulk terminals of gasoline. These were studied in two groups, depending on location.

There are 3,230 gasoline storage tanks, with an average capacity of 2,814,000 gallons (67,000 bbl) and 7,350 crude oil storage tanks, with an average capacity of 2,100,000 gallons (50,000 bbl) associated with refineries. It is estimated that 75 percent of all gasoline and crude oil storage tanks are presently equipped with floating roofs to control hydrocarbon emissions.

At the bulk terminals, in every state but Delaware, a smaller tank with an average capacity of 890,000 gallons is typical. Again, about 75 percent of the tanks are estimated to be equipped with floating roofs. About $4.8 million was spent in 1971-1973 to reach this control level.

C. Catalyst Regeneration

New Source Performance Standards will apply to new units for catalyst regeneration in the petroleum refining industry. The anticipated growth is equivalent to two new 65,000 barrel/day and one new 20,000 barrel/day fluid catalytic cracking units per year. Emissions from the larger units, at previous design levels, would be 695 tons of particulates and 3948 tons of carbon monoxide per year; emissions from the smaller units would be 213 tons of particulates and 1075 tons of carbon monoxide per year.

With a further investment of $1.15 million, a 65,000 bbl /day unit can be controlled to an annual emission level of 157 tons of particulates. An investment of $0.7 million permits control to an annual emission level of 43 tons of particulates. This control, industry-wide, reduces the particulate emission in fiscal 1978 to 1,785 tons, from 7,015 tons without additional control.

D. Storage Vessels

Storage vessels for hydrocarbons are the subject of a proposed new source performance standard. The standard would require a floating roof for storage tanks with vapor pressures above 1.5 psia and a vapor recovery system for liquids with vapor pressures above 11 psia. The costs of these requirements (about $26,000 for a 50,000 bbl gasoline storage tank) are offset by the savings from the recovery of hydrocarbons. For an 80,000 bbl tank, savings would be $11,000/yr for gasoline, $5,200/yr for crude oil, and $1,000/yr for jet naptha. About 75 percent of existing storage tanks have floating roofs.

E. Coal Cleaning

1. General Description

Coal from the mines is prepared in response to market demand. Three types of preparation plants are common: 1) "complete preparation," those that clean both coarse and fine coal; 2) "partial preparation," those that clean only coarse coal; and 3) "coal crushing," where the coal is merely crushed to a maximum size specification.

In a complete coal preparation facility, coal from the mine is broken and screened to remove oversize material, then stored until the batch processing in the plant is begun. Crushing is sometimes necessary to ensure good separation in the cleaning plant. Classifying screens separate coal particles by size and route them to various cleaning processes represented by the "cleaning process" portion of the diagram. In general, this cleaning process may be wet, dry, or a combination of both.

Normally water is used; about 7 percent of coal washing uses air in pneumatic washers. About 21 percent of the wet washed coal is dried in thermal driers of flash or fluidized bed type. There appears to be a long-term decrease of 5 percent per year in the practice of drying the cleaned coal; more of the washed coal is shipped wet to the user.

2. Wet Cleaning Systems

Wet cleaning systems use centrifugal or gravity separation of heavier rejects from coal, and generally do not emit air pollutants. However, the auxiliary processes of handling and drying can be major sources. After the coal is wetted by the cleaning process, the operator normally dries it to minimize weight, thereby decreasing shipping costs, and to prevent freezing during winter months. The first stage of drying is often a simple mechanical dewatering screen followed by centrifugal driers.

Where customer demand is for low surface moisture (3 to 6 percent) of finer coal sizes, secondary drying is required. Such low moisture levels can only be accomplished by thermal drying. It appears that new coal preparation plants that install thermal driers will use a fluid-bed type.

In the fluid-bed drier, hot combustion gases from a coal-fired furnace are passed upward through a moving bed of wet coal of fine particle size. As the bed fluidizes, the coal is dried as the fine particles come into intimate contact with the hot gases. Particulate emissions occur predominantly from ultrafine (-200 mesh) coal particles which are entrained and carried from the drier by the combustion gases.

The primary control device, a dry centrifugal collector used principally to recover product, can retain up to 95 percent of the entrained fines. These are returned to the product coal. All secondary emission control systems are wet collectors. The high dew point and explosion potential of the exhaust gas makes other emission control systems impractical.

The dried coal is conveyed to storage, where it remains until being loaded into railroad cars, trucks, or barges.

3. Dry Cleaning Systems

About 7 percent of coal washing uses air in pneumatic washers. Coal containing refuse particles enters the air table, where it is stratified into a bed by pulsating air. The heavier refuse settles in a layer beneath the coal. As the bed travels forward, the refuse drops into packets or wells from which it is withdrawn to the refuse bin. The upper layer of coal is removed as it completes its travel over the slowly moving bed of refuse. Dust, airborne by the pulsating air, is drawn into an overhead hood to be recovered by a cyclone dust collector; cyclones are installed by the operator for product recovery. Secondary collectors, which are the air pollution control device, are usually fabric filters.

4. Emissions and Methods of Control

Emissions from uncontrolled coal preparation plants consist of NO_x, SO_2, CO and fine particulates generated or airborne by thermal drying. Particulate emissions alone come from crushing, screening, storage, transfer, grinding, conveying, or loading operations. Particulate emissions, at times severe and highly visible, increase as surface moisture in the coal decreases. Particulate control requires good collection of the emissions which must then be discharged to a control device.

Thermal driers in the wet cleaning circuit use cyclones as an integral part of the process. Particulate emissions upstream of the cyclone have been measured in the range of 50 to 200 grains per dry standard cubic foot (gr/dscf) for fluid-bed driers. Emissions downstream of the cyclones have measured from 0.7 up to 14.4 gr/dscf. An average emission factor often used for fluid-bed driers without secondary control is 3.0 gr/dscf. (At 3.0 gr/dscf, a 500-tons-per-hour thermal drier without secondary control would emit over 5,000 pounds of particulates per hour.)

Well-controlled thermal driers use high-energy venturi-type wet scrubbers to reduce particulate emissions. The investment cost for venturi scrubbers to remove particulates from the drying gas stream depends on the rate of flow. Air flow, per ton of coal processed in an hour, is typically 360 cubic feet per minute for pneumatic cleaners, 480 cfm for fluidized bed driers, and 580 cfm for flash driers. With the type of control device selected, cost is affected by which of these air flow processes is used, but is approximately $120,000 for a plant with a gas flow of 50,000 cfm.

An investment of some $12 million is projected for abatement devices installed in fiscal 1974-1978. Annual costs in fiscal 1978 will be $2.9 million. These costs will reduce the fiscal 1978 particulate emissions by this industry from 71,000 tons to 26,000 tons.

F. Natural Gas Production

The domestic production of natural gas, increasing by about 0.55 percent per year, is expected to reach 26.2 trillion cubic feet in 1978. Control of sulfur dioxide emissions from the tail gas of Claus sulfur plants calls for the installation of a tail gas scrubber, which can achieve an overall capture of 99.5 percent of the input sulfur of the raw gas processed. There are currently 84 Claus units at natural gas production facilities. Elsewhere, amine scrubbing is practiced.

A breakdown of control costs by State to meet ambient air quality standards is presented in Table 5-11.

TABLE 5-11. Direct Costs 1974-1978 Natural Gas Production Plants in Place, 1970

State	Costs (1,000's of dollars)		Emissions (tons/year)	
	Investment	Annual	Before control	After control
Alabama	1,940,000	510,000	12,624	972
Arkansas	1,295,000	345,000	6,240	480
California	740,000	195,000	4,080	314
Florida	1,850,000	492,000	6,355	635
Mississippi	4,535,000	1,216,000	62,256	4,798
New Mexico	1,650,000	435,000	5,424	416
North Dakota	300,000	78,000	960	74
Oklahoma	420,000	110,000	1,104	84
Texas	22,441,000	5,967,500	130,368	10,085
Utah	190,000	51,000	480	37
Wyoming	7,210,000	1,923,000	44,112	3,397

To meet ambient air quality standards for sulfur oxides emissions, the industry is expected to invest $43.65 millions over the next five years, with an annual cost in fiscal 1978 of $11.8 million. This will reduce industry-wide emissions of sulfur oxides, expressed as sulfur dioxide, to 22,100 tons. Without additonal control, the emission level in fiscal 1978 would be 276,000 tons.

G. Burning Fuel Gas

To meet the requirement of reducing the hydrogen sulfide (H_2S) of fuel gas to new boilers and heaters would require additional amine scrubbing as well as additional Claus unit capacity to convert the scrubbed H_2S to sulfur. Since the fuel gas is traditionally scrubbed (usually to about 200 gr/scf), there is basically no investment or operating cost difference between a new installation designed to meet the equivalent of 200 gr/scf and one designed to meet 0.1 gr/scf. However, there will be additional costs for the incremental Claus capacity required. It is estimated that there will be a requirement of approximately 9 new 15 long ton/day Claus units per year to meet the standard.

A 15 long ton/day Claus unit costs about $350,000 and may be operated with an annual expense about equal to the worth of the recovered sulfur at $20/ton. Such a unit reduces the industry total for sulfur dioxide emissions from 540,000 tons to 27,000 tons in fiscal 1978.

V. BIOCHEMICALS INDUSTRIES

A. Grain Handling and Milling

1. Industry Description

Grain elevators which load, weigh, store, and unload grain and have capacities less than one million bushels are found in 47 of the States. These country elevators are to be distinguished from the larger terminal elevators, which also clean, dry, blend, and occasionally turn the grain they store. Country elevators are typically operated 2500 hours per year, with an average annual throughput of 220 percent of capacity. In contrast, the larger terminal elevators are operated almost full time but with a slower average annual throughput, about 150 percent of capacity.

The bulk of grain (normally wheat, corn, oats, barley, rye, or soybeans) is transported from the farm to the country elevator operator. Grain is unloaded from farm trucks, weighed, inspected, and transferred to a storage bin. Once a buyer has been found, the grain is loaded (normally by spouting) into a prepared railroad car, truck, or barge. The function of the elevator is not primarily to store, but to hold the grain until a market can be found in the large centers of accumulation--at processing plants, large mills, and terminal elevators. The physical process is quite simple.

If the grain is not sold to a local mill, exporter, or other outlet, it is transferred to the terminal elevator operator. Terminals are very large elevators (up to and exceeding capacities of 10 million bushels), generally located at significant grain trade cities. The function of a terminal merchant is to store the grain without deterioration in quality and to bring it to commercial grade so as to conform to the needs of buyers. Handling parellels that at the country location, but terminal merchants are the first to thoroughly clean, dry, separate, and store the grain at proper temperature and humidity. Grain moving out from terminals is ultimately used for food, feed, export, or industrial purposes.

2. Emissions Control

Large quantities of particulates are airborne during the handling of grains, principally due to mechanical abrasion between kernels and the loosening of adhered dirt from the field. Because operations are normally located in rural areas, there has historically been little emphasis placed on air pollution control practices which exceed the level required for economical recovery of materials, reduction of explosion hazards, and general good housekeeping. Consequently, low efficiency cyclone separators have been the most commonly employed control devices in the industry.

The dust emitted as a result of these operations amounts to about eight pounds of particulates per ton of grain handled in a country elevator, and 23 pounds per ton handled in a terminal elevator. A fabric filter system to control these emissions could remove them with 99 percent efficiency, but present control averages about 28 percent efficiency.

For this control, an investment of $492 million is required over the next five years. This will result in an annual cost in fiscal 1978 of about $113 million, and a reduction in particulate emissions from 1.3 million tons to 23,000 tons in fiscal 1978.

The milling of grain results in about 18 pounds of particulate emissions per ton of feed. However, current practice is to remove about 35 percent of these emissions. A fabric filter system could further improve this to 99 percent control. With an investment of $21.6 million, and annual costs of $4.1 million in fiscal 1978, such a system would reduce emissions by this industry to 4,600 tons from 232,000 tons emitted under present practice.

B. Forest Products

The manufacture of forest products results in residues such as bark, sawdust, slabs, trim, and shavings. Only about half the log entering a sawmill or plywood plant emerges as lumber or plywood. Disposal wastes by incinerator in a wigwam (teepee) burner has been a common practice. Economic utilization of the residue is reducing the quantity incinerated, but where markets do not exist, incineration is still the only practical disposal method.

Control of wigwam burner emissions can be effected by improving and controlling combustion so that the carbon monoxide and particulates resulting from incomplete combustion are reduced. While controls are aimed, primarily, at reducing particulates, carbon monoxide emissions are reduced by a proportionately greater amount. Control is obtained by providing properly proportioned forced underfire and overfire air, a top damper, and auxiliary fuel for start-up and burn-down so as to quickly attain and maintain temperatures above 700° F. A thermocouple and bolometer provide for automatic operation of the system. An alarm system and a recorder are included for monitoring operations.

Residue from the forest products industries is being utilized increasingly for pulp, chip board, steam generator, charcoal, soil amendments, mulch and landscaping, and the production of waxes and chemicals. Residue utilization is developing rapidly. By 1978, forest products plants using wigwam burners to dispose of residue are expected to be about 25 percent of those in 1970. In the South within two years, each forest products plant is expected to have at least two markets competing for the residue produced. In the more populated States of the East and industrial Midwest, residue markets are expected to take everything available by 1978. The same is expected eventually for the Pacific Coast States, although it may be somewhat later than 1978. Complete residue utilization will occur latest for plants located in the less populated States and in States where forest products industries are less concentrated.

For the remaining wigwams in 1978, combustion control equipment to reduce emissions is estimated to have required an investment of $70.6 million, with an annual cost in fiscal 1978 of $6.6 million. This will result in a reduction of particulate emissions in that year from 84,500 tons without the control equipment to 16,900 tons with it. Carbon monoxide emissions will be lowered from 275,000 tons to 39,300 tons by this action.

C. Carbon Black

The two basic methods of carbon black manufacture are the furnace process and the channel process. Furnace process plants are controlled to at least 97 percent efficiency, with a large number controlled to 99.5 percent. A reasonable average for the furnace black segment of the industry is probably 99 percent.

The four channel black plants in existence are not controlled and would be difficult to control since methods have not been developed to recover the black from the vent gases. Attempts to separate the black in the smoke upset the production process and result in diminished quantity and quality of the product.

What the States of Texas and New Mexico will do with respect to the four channel black plants can be to grant a variance or attempt to have the plant closed. Furnace black plants require no additional control and, therefore, no added cost.

Future growth of 4.7 percent for the industry can be expected to be in the furnace process. These plants will provide 99 percent control. With this growth, the emissions of particulates in fiscal 1978 will reach about 237,000 tons.

D. Kraft Pulp

Several methods are used to produce pulp from wood for use in making paper and related products. Of the chemical methods, the kraft sulfate process can cause significant air pollution. Some estimates of the particulate emissions as a result of each step of the kraft process are presented in Table 5-12.

TABLE 5-12. Kraft Pulp Particulate Emission Factors

Process	lb. particulates/ton pulp Uncontrolled	1970 control level
Recovery kiln	151	13.6
Lime kiln	45	21.5
Smelt tank	5	0.3
Bark boiler	4.5	4.5

In the kraft process, which accounts for approximately 64 percent of the pulp industry output, woodchips are cooked in a liquor composed of sodium hydroxide and sodium sulfide to separate the lignin from the cellulose. Pulp is produced from cellulose. The lignig is burned as a fuel in the recovery furnace, to satisfy the energy requirements for the pulping process. The chemicals recovered from the salt cake solution (black liquor) are recycled. Three portions of the process emit significant quantities of particulates : recovery furnaces, lime kilns, and bark boilers. The level of sulfur dioxide emissions from the main source, the recovery furnace, generally does not exceed 500 parts per million.

State Implementation Plans for these particulate emissions are generally stated in permissible emission rates; typically, the requirements lead to 97 to 99 percent control of emissions. To achieve such control, recovery kilns and lime kilns may be provided with a Venturi scrubber, smelt tanks with an orifice scrubber, and bark boilers with a multicyclone scrubber. This would result in an industry-wide investment over five years of $108 million with an annual cost in fiscal 1978 of $46 million. Control would reduce particulate emissions in 1978 from 960,000 tons to 80,000 tons.

VI. QUARRYING AND CONSTRUCTION

A. Overview

Quarrying and use of rocks, sand, and minerals on a large scale readily results in large amounts of dust generated and blown into the atmosphere. As a result, the industries presented in this section are characteristic emitters of particulates. Furthermore, this is the exclusive output of these industries as far as clean air is concerned.

B. Quarrying

1. Crushed Stone, Sand, and Gravel

It has been estimated that the quarrying and transport of stone, sand, and gravel for construction purposes resulted in 4.6 million tons of airborne particulates in 1970. Assuming a growth rate of 3 percent, equal to the composite of the asphalt and cement industries, the emission level would rise to 5.05 million tons in 1973 and 5.87 million tons in 1978. However, about half of these particulates settle out within the confines of the industrial site. No control has been proposed for this emission, although practices such as routing of trucks away from residential sectors, etc, are commonplace.

2. Limestone Crushing

Limestone crushing, primarily to provide raw material for the lime industry, generated about 264,000 tons of airborne particulates in 1970. Growing at a rate equal to that of the lime industry, this activity will generate 390,000 tons of particulates in fiscal 1978.

No control procedure appears feasible for this industry.

C. Cement

1. Industry Description

Although the Portland cement industry presently suffers from overcapacity, a net growth of 21 percent in capacity is expected by June 1978. This growth after 1973 must meet the New Source Performance Standards for particulate emissions by cement plants.

Portland cement, which accounts for approximately 96 percent of cement production in the United States, is a blend of materials such as chalk, clay, limestone, and shale. As the binder in concrete, Portland cement is the most widely used construction material in the United States and the world.

The four major steps for producing Portland cement are: (1) quarrying raw materials and reducing their size, (2) grinding and blending these materials to obtain proper composition and uniformity, (3) heating the materials in a rotary kiln to liberate carbon dioxide and cause fusion, and (4) fine grinding the resultant clinker, which is sold in bulk or bagged. All Portland cement is produced by either a wet or dry process with the chief difference being whether the raw materials are introduced into the kiln as a dry mixture or as a wet slurry.

2. Emissions and Cost of Control

Particulate matter is the primary emission in the manufacture of Portland cement. Emission sources include: (1) raw material crushing; (2) raw material drying and grinding; (3) kiln operation; (4) clinker cooling; (5) finish grinding and packaging; and (6) various other points such as material conveyance and storage. Sulfur oxides are also formed from the combustion of fossil fuels during kiln operations, but these are mostly eliminated through combination with calcined lime within the kiln.

The raw drying-grinding mill (dry process only), the rotary kiln, and the clinker cooler are the major points of emission. Other sources are already controlled to high degrees for economical reasons as the collected material is usually returned to the process.

Cement plants using the dry process are expected to employ fabric filters. Plants using the wet process can be controlled with an efficiency up to 99.3 percent by electrostatic precipitators; beyond this, an insulated baghouse must be used where higher efficiency of control is necessary. The costs of insulation for the wet process control raises baghouse investment by about 30 percent.

Uncontrolled dry process plants emit 46 pounds particulates per barrel processed, and uncontrolled wet process plants emit 38 pounds particulates per barrel processed. In fiscal 1978, new plant construction and partially controlled existing plants would as a result provide 432,000 tons of particulates emitted by the industry. Emission controls will reduce this to 37,000 from older plants and 3,000 from new plants. Investment through 1978 for controls is $107 million for improving old plants and $38 million for new plant controls. Annual costs are $66.2 million for plants built before fiscal 1974 and $7.35 million for plants built in fiscal 1974 to 1978.

D. Asbestos Industries

1. Asbestos Milling

The emission standard proposed for asbestos milling prohibits visible emissions of particulates from ore dumps, open storage areas, external conveyors, or tailings dumps for asbestos-containing materials. Emissions from ore dryers, process air streams, milling operations, and manufacturing operations are to be filtered to reduce particulate levels to the permissible concentration. Typical emissions control costs are shown in Table 5-13.

TABLE 5-13. Emission Control Costs in Asbestos Milling

Control Unit	Investment ($/CFM)	Operation & Maintenance ($/CFM-Year)
Cyclone collector	0.55	0.13
Baghouse		
Low temperature	3.00	0.90
High temperature	6.00	1.30

Currently, there are nine asbestos mills in the United States, with a combined capacity of 163,600 tons of asbestos per year. The industry is expected to grow at a rate of 1.6 percent per year. This will probably occur through expansion of production at existing mills; no new mills are anticipated.

For an investment of $506,000 and annual costs of $232,000, the industry can remove 99 percent of the estimated 4,300 tons of particulate asbestos fibers it would otherwise release in fiscal 1978.

2. Sprayed Asbestos Fireproofing and Insulation

Asbestos-cement insulation is applied to steel-frame and steel-reinforced buildings as thermal insulation and fireproofing. Other formations are used for high temperature or acoustic insulation. Although only small amounts of asbestos are emitted from these uses, they are of significant concern because of their concentration in urban areas. Emissions of asbestos in this process arise from handling of the dry mixture, escape of unwetted fiber and mixture, overspray and backsplash, cleanup and disposal of wastes, and demolition of structures where asbestos products have been used.

The proposed control is to ban these uses of asbestos when applied to a building or when the application is open to the atmosphere. Asbestos emissions from these sources would be reduced from an estimated 15 tons per year to nearly zero. There are alternative materials available such as mineral wool, and ceramic and glass fibers, which yield comparable results at a modest increase in cost. When it is considered that the cost of materials is only a small part of the total cost of the application of insulation, and that insulation is a minor expense in total construction, the impact would not be significant. In fact, it is usually cheaper to use a different material than to apply other control techniques.

3. Asbestos Products

Asbestos fiber is widely used for its durability, inertness, and insulation. Five major groupings of asbestos products, accounting for over 93 percent of the fiber consumption by the United States, were studied for the costs of emission control to meet current air quality standards for particulates. These groupings are given in Table 5-14.

TABLE 5-14. Asbestos Products Emissions

	Percent of total annual consumption	Potential emissions (pounds per ton of fiber consumed)	Percent of potential emissions currently controlled
Asbestos Cement Products	50.2	4	75
Asbestos Floor Tile	24.5	4	75
Asbestos Friction Materials	12.7	120	95
Asbestos Paper	3.7	4	75
Asbestos Textiles	2.2	40	95

The manufacture of these products consumes 412.5 thousand tons of asbestos and, in 1970, resulted in the release of about 204 tons of airborne particulates. Control, in the form of hooding and installation of fabric filters, is projected to meet a national emission standard of one percent of uncontrolled emissions.

In fiscal 1978, with an industry growth of five percent per year, this control will have required a 1973 to 1978 investment of $7.83 million. Annual costs will be about $1.75 million, exclusive of monitoring. These expenses will reduce the projected emission of particulates in 1978 to 116 tons, from about 690 tons with current control practices.

E. Asphalt Concrete

Asphalt concrete for paving generally consists of about 5 percent asphalt and 95 percent crushed stone. The crushed stone aggregate is dried, sized, and blended with hot asphalt and mineral filler at a batching plant. Brought to the paving site by trucks, the hot mixture is then spread and compacted into a smooth surface.

Drying, moving, sifting, weighing and mixing operations in the hot-mix plant producing asphalt concrete are sources of particulate emissions to the atmosphere. Cyclone collectors are usually installed. These control emissions to some degree and recover and recycle fine aggregate.

To meet State regulations, additional particulate control is usually necessary. Venturi scrubbers are the popular choice, resulting in emission control of about 96 percent. Fabric filters are chosen when more control is required. The operating costs are lower but the initial investment is greater when a fabric filter is chosen over a scrubber.

It has been estimated that the cost to the industry for meeting ambient air quality standards will be about $199 million for additional equipment. This amounts to about $43,000 per plant, although, of course, individual plant costs can be expected to vary widely depending on location, current emission control, and difficulty of retrofit of new controls.

In addition to air quality standards, it has been proposed that new plants in this industry meet a new source performance standard.

The standard being considered will limit new plant emissions to 0.03 grain per dry standard cubic foot as a maximum 2-hour average and opacity of the emissions to less than 10 percent with corrections made for water vapor. Dilution of excessive emissions by excess air to meet the standard will be disallowed.

The cost of emission control for new sources does not increase in proportion to the plant capacity. This means that the greatest economic impact will be on the smallest plants. This would result in a reinforcement of the current trend away from plants with capacities of 150 tons per hour and less, and to plants with capacities of 300 tons per hour and more.

The industry currently is growing at a rate approaching 6 percent per year. In addition, with an average 10-year life for asphalt concrete plants, there is a replacement rate of 10 percent yearly. The current annual output of the industry is 320 million tons, from 4500 existing plants.

The capacity of existing plants can be typified by four representative sizes:

Average size in group	Fraction of plants
75 ton/hr	20%
125 ton/hr	35%
175 ton/hr	30%
225 ton/hr	10%

All plants considered, this is equivalent to an average capacity of 135 tons/hr. It is clear that the 4500 existing plants need not operate very often to achieve the current annual output of 320 million tons.

Typical new plants can be expected to have a capacity of 300 ton/hr. To provide for replacement of old plants and an industry growth of 6 percent, some 320 new plants are required annually. The investment in a fabric filter particulate control and dust removal system has been estimated at $135,000; the operating cost has been estimated at $37,000 annually.

With these figures, one can project an industry investment as a result of new source performance standards. The projections come to $43.2 million invested annually and $11.8 million operating costs as a result of this investment.

These new plants, providing 16 percent of the asphalt concrete production capacity, will compete for 16 percent of the market for 340 million tons. Their share comes to 54.5 million tons. Dividing the annual operating costs evenly among this production indicates a cost increase of under 35 cents per ton, over what would be required if the plant operated with no control. The average value per ton of asphalt concrete in 1971 was $6.08.

The asphalt industry investment in emission controls for fiscal 1974 to 1978 is estimated to be $544 million, with an annual cost of 132 million. This will reduce particulate emissions in fiscal 1978 from 2,184,000 tons to 1,577,000 tons.

VII. CHEMICALS

A. Overview

Four industries producing inorganic chemicals are presented here.

GROUP 5: CHEMICALS INDUSTRIES

Lime
Sulfuric Acid
Nitric Acid
Phosphate Fertilizer

B. Lime

1. Industry Description

Lime is a calcined or burned form of limestone, commonly divided into two basic products--quicklime and hydrated lime. Calcination expels carbon dioxide from the raw limestone, leaving calcium oxide (quicklime). With the addition of water, calcium hydroxide (hydrated lime) is formed.

The production of lime is growing at about 5 percent per year. The proposed uses of lime for sulfur dioxide removal from stack gases, and as a precipitant in municipal waste treatment may significantly raise the growth rate.

The basic processes in production are (1) quarrying the limestone raw material, (2) preparing the limestone for kilns by crushing and sizing,

(3) calcining the feed, and (4) optionally processing the quicklime further by additional crushing and sizing and then hydration. The majority of lime is produced in rotary kilns and shaft (vertical) kilns; both can be fired by coal, oil, or gas. Rotary kilns have the advantages of high production per man-hour and a uniform product but require higher capital investment and have higher unit fuel costs than most vertical kilns. The open market lime industry shows a trend toward installation of larger rotaries with a far higher capacity than vertical kilns.

Reduction of limestone is accomplished usually in rotary kilns, typically capable of handling 2 to 600 tons/day; about 20 percent of lime is calcined in vertical kilns, with a typical capacity of 10 to 50 tons/day. For the larger, rotary kilns, State Implementation Plans call for an efficiency of removal of particulates from the airstream in the range of 98.8 to 99.4 percent. High efficiency wet scrubbers are most effective in meeting this requirement. For the smaller, vertical kilns, State Implementation Plans call for efficiency of removal of particulates in the range of 77 to 85 percent, and a low energy wet scrubber would often suffice.

2. Emissions and Costs of Control

Air pollution in the lime industry consists primarily of particulate emissions in the form of limestone and lime dust. The main source of these emissions is the calcination process; the peripheral processes of crushing, pulverizing, sizing, and conveying of the feed material are also significant potential sources. Since most modern plants adequately control the peripheral processes for economic and industrial hygiene purposes, only the kiln emissions will be considered in this analysis.

Most rotary kilns are equipped with dry mechanical collectors which remove an average of 75 percent of the particulate effluent. The application of low-energy venturi or two-stage dynamic scrubbers to the smaller rotary kilns (less than 500 tons per day) and fabric filters to the larger rotary kilns (500 tons per day and larger) would allow this segment of the industry to achieve the assumed process weight rate standard at an overall control efficiency of 98.9 percent.

Vertical shaft kilns account for virtually all of the remaining lime production. These kilns tend to be smaller in capacity and to emit significantly less dust, about 1 percent of the lime produced. Few, if any, vertical kilns are presently equipped with control devices. The assumed process weight rate standard could be met by adding cyclonic scrubbers, resulting in an 88.5 percent overall control efficiency.

Uncontrolled emissions from rotary and vertical kilns are 200 and 8 pounds per ton of product, respectively, but present controls reduce these emissions to about 58 and 5 pounds, respectively. To control emissions to the mandatory level will require an industry investment in the next five years of almost $40 million, and an annual cost in that year of $13 million.

C. Sulfuric Acid

1. Introduction

Sulfuric acid is the largest single chemical product in the United States. It is used in the production of phosphate fertilizers and other industrial chemicals, in the purification of petroleum, the leaching of copper ore, and the pickling of steel.

Almost 97 percent of all sulfuric acid is produced by the contact process. Generally in this process, sulfur or pyrite is burned to form sulfur dioxide (SO_2) which is then catalyzed to sulfur trioxide (SO_3). Sulfur trioxide is absorbed in sulfuric acid to form more concentrated grades of sulfuric acid and oleum. An increasingly important source of sulfur dioxide is that liberated during the smelting of sulfide ores bearing copper, nickel, zinc, and lead. The final 3 percent of acid is produced by the obsolete and costly chamber process, but because this process is rapidly being phased out, it will not be emphasized in this analysis.

2. Emissions and Cost of Control

Pollutants consist of sulfur dioxide escaping catalytic conversion and acid mists emitted from the absorption tower. Most plants today operate with a single absorption step resulting in a sulfur dioxide to sulfur trioxide conversion of 96 to 98 percent. To comply with the assumed emission standard requires upgrading the conversion efficiency to 99.5 percent or tail gas scrubbing with alkaline solutions. (New acid plants are expected to achieve 99.7 percent conversion efficiency.) This would result in a reduction of 86 percent from the existing emission level of a typical acid plant. To accomplish 99.5 percent conversion requires partial removal of the sulfur trioxide formed, via primary absorption, which improves the oxygen-to-sulfur dioxide ratio for favorable conversion of the residual sulfur dioxide. Secondary absorption is required to complete the recovery of sulfur trioxide as acid.

It is estimated that two new sulfuric acid plants of capacity 1500 tons per day will be constructed each year to meet the growing demand for sulfuric acid. Sulfur dioxide is, of course, the pollutant of major concern in this industry, but acid mist particulates are also of concern. Some idea of the costs of controlling these pollutants can be obtained from the following tables.

Investment costs for the industry in fiscal years 1974 to 1978 to meet Ambient Air Quality Standards total $128.7 million for sulfur dioxide and $12.1 million for particulates. To meet New Source Performance Standards, they total $18 million for sulfur dioxide and $570,000 for particulates. A total of $159 million is required for emission control by this industry, and annual costs are expected to be near $29 million.

TABLE 5-15. Tubular Demister Control Costs

Plant Capacity tons/day	Investment Cost ($1000)	Annualized costs ($1000) 99% H_2SO_4 Plant	Annualized costs ($1000) Oleum Plant
50	78	23.0	19.0
250	100	30.5	25.9
750	150	47.2	37.5
1500	240	62.0	52.0
2000	290	69.0	58.0

TABLE 5-16. Dual Absorption Costs for SO_2 Control

Plant Capacity tons/day	Investment Cost ($1000)	Annualized cost ($1000)
50	260	22.5
250	482	67.5
750	920	141.5
1500	1450	266.4
2000	1750	340.0

D. Nitric Acid

The industry synthesizing nitric acid from air and ammonia is growing at a yearly rate of one new plant of 300 tons/day. Emission control costs for the new plants, to meet New Source Performance Standards, are negligible, inasmuch as the industry has adopted the new D. M. Weatherly plant design, which meets the standard of no more than 3 pounds of nitrogen oxides emitted per ton of acid produced.

Older plants emit up to about 62 pounds of nitrogen oxides in the tail gases for each ton of acid produced. For control of a 300 tons/day plant, an investment of $400,000 in a selective abator is adequate. Without this additional control, an emission of about 115,000 tons of nitrogen oxides can be expected in fiscal 1978. Control reduces this to 12,400 tons, with a five-year investment of $16.5 million and an annual cost of $5 million.

D. Phosphatic Fertilizers

1. Industry Description

Phosphate rock is processed into many products used in the United States. Chiefly, these are agricultural fertilizers (75 percent), animal feed supplements, elemental phosphorous, and phosphoric acid.

Complete or balanced fertilizers involve the production of P_2O_5 ("phosphate") from phosphate rock and mixing this chemically and/or mechanically, with nitrogen and potassium nutrients. Plant foods are produced in various NPK (nitrogen, phosphorus, potassium) grades to fit varying soil requirements.

The manufacture of the phosphate for fertilizers begins with the preparation of rock for processing. Ground rock is treated with sulfuric acid to produce either normal superphosphate fertilizer (20 percent P_2O_5) or wet process phosphoric acid. This acid intermediate (about 54 percent P_2O_5) may be used to produce diammonium phosphate (18 percent nitrogen and 46 percent P_2O_5) or triple superphosphate (46 percent P_2O_5). Superphosphoric acid (about 70 percent P_2O_5) is produced by dehydration of wet process phosphoric acid and used in the preparation of mixed liquid fertilizers for direct application to the soil.

2. Emissions and Costs of Control

Dusts, acid mists, sulfur dioxide, fluorides (gaseous and particulate), and ammonia are emitted from various processes in the phosphate fertilizer industry. Dusts are emitted from drying and grinding of phosphate rock, calcination, drying and cooling in the granulation process (the major source), and conveying, bagging, and other handling operations. Sulfur dioxide is emitted from the sulfuric acid plants owned by some major phosphate processors that produce wet process phosphoric acid. (Sulfuric acid production was discussed in detail above; the control costs described in that section have their major economic impact on the fertilizer industry.)

The production of diammonium phosphate, triple superphosphate, and NPK fertilizers generates airborne particulates through the screening and drying of phosphate rock and the cooling of the granulated product. The only part of the industry that is projected to grow is the production of diammonium phosphate; this at a rate of 4.2 percent per year.

Control of emissions by some 53 phosphate plants (both DAP and TSP), and some 354 NPK plants can be achieved with high efficiency venturi scrubbers. Typical costs would be:

Plant type	Capacity (T/yr)	Investment	Annual cost
DAP	120,000	$125,000	$ 64,000
TSP	190,000	390,000	177,000
NPK	50,000	15,000	34,000

These costs result in an industry investment through fiscal 1978 of almost $39 million and annual cost of almost $23 million. Without this additional control, the fertilizer industry would generate 348,000 tons of airborne particulates in fiscal 1978. With this control, emissions drop to 32,000 tons.

CHAPTER 6. FOSSIL FUELS

I. INTRODUCTION

A. Outline of the Chapter

Most air pollution and the expense of reducing it come from burning coal, oil, and gas. A glance at the subtotals in Table 1-3 shows how much larger is the problem of control of this activity, compared with all other industrial activities. The mobile sources of the transportation sector were review in Chapter 4. The discussion presented here covers the stationary sources which depend on burning of fossil fuels.

By 1978, burning of fossil fuels by stationary sources can be expected to generate 60 percent of all sulfur dioxide emissions, even with proposed controls. As well, major amounts of particulates and oxides of nitrogen will be emitted by these sources. Reduction of these emissions will require a major application of new technologies and examination of the alternatives. Regulations presently enacted provide for such reduction within the next few years. Each affected industry will, therefore, be faced with the need to make major decisions as to the acceptable alternative it will choose. The principal alternatives for pollution abatement are presented in Sections II, III, and IV of this chapter. This presentation is perhaps overly long, but warranted in view of the importance of the decisions to be made.

With the uncertainty as to course of action, a prediction had to be made arbitrarily. Reliable predictions depend, of course, on future trends being merely continuations of past trends. Only if this sort of stability occurs in technology, international politics, and resource reserves does the prediction hold. The reader must supplement the conclusions presented herein with what is to transpire after this analysis. Expectations for the future rarely materialize to three significant figures.

Two groupings of stationary sources are presented. Household, commercial, and industrial consumers of fossil fuels are combined as one grouping in Section of this chapter. Industrial consumers generate the bulk of emissions by this grouping. Steam-electric power plant emission control strategy is presented in Section of this chapter.

Because household, commercial, and industrial consumers are the end consumers of electric energy, a breakdown of the distribution of electric energy consumption is appropriate here. Of the 1970 electric energy consumption,

- 31.9 percent went to residential use,
- 22.4 percent went to commercial, and
- 41.4 percent went to industrial.

Other miscellaneous users consumed the remaining 4.3 percent. Knowledge of the ultimate distribution of energy consumption permits assigning the costs of control to their appropriate sources.

B. Scope of the Problem

There is no cheap fuel with combustion products that are acceptable as non-polluting. The problem, therefore, is to choose among the available fuels and to provide sufficient environmental protection from their combustion products so as to meet protection standards while generating heat and power as economically as possible. In the near term, energy resources that will be consumed in large amounts are nuclear fuels with their radioactive waste disposal requirements, and the fossil fuels with their ash residue disposal and gaseous emission control requirements.

Of the fossil fuels, natural gas is the cleanest, but is in short supply. Consider the pollutants that an uncontrolled steam-electric plant producing 1000 megawatts would emit without control:

Table 6-1. Uncontrolled Emissions From a 1000 Mwe Plant (lbs/hr)

Fuel	Particulates	SO_2	NO_x
Coal	67,400	32,000	8430
Oil	670	21,000	6930
Gas	140	4	3730

As Table 6-1 indicates, natural gas is preferable from an emissions standpoint. Indeed, gas-fired power plants provided 23 percent of electricity in 1970, and gas provided one third of all heat energy derived from fossil fuels. However, the consumption of gas during the near term is expected to remain fairly constant, and growth in fossil fuel demand will be taken up by coal and oil. The scarcity of natural gas, which represents about 4 percent of the known fossil fuel potential thermal inventory, is to blame for this lack of expansion.

Petroleum is a relatively abundant fuel, at least internationally. The domestic production is becoming increasingly critical due to limited reserves and increasing demand. The deficit is being met by imports. Mobile sources, using gasoline and diesel oil, provide one-half of the demand. Stationary sources, using distillate and residual fuel oil, provide the rest. Distillate, like natural gas, has a low sulfur content generally meeting sulfur regulations. The ash content of fuel oil, about 0.05 percent, does not present a major emission problem.

The most abundant fossil fuel in this country is coal. In 1970, about 320.5 million tons of coal were burned to supply about half of United States elecrtic power. In the same year, 100.5 million tons were used for heating, 98 million tons were used as coke in industrial processes, and 73 million tons were exported. The resources of coal are widespread through the U.S., but coal has not been used in proportion to its availability.

Coal typically has an ash content of 9 percent, of which under uncontrolled conditions about 85 percent would be emitted from a dry-bottom boiler, and 65 percent from a wet-bottom boiler. The resulting emissions would be orders of magnitude (as Table 6-1 shows) higher than those from the combustion of the other fossil fuels. Particulate control is found on all but the smallest coal burners.

Sulfur dioxide emissions from coal burning are even more serious and more difficult to control. In 1970, the sulfur content of coal burned by utilities, industry, and in heating units for household and commercial use averaged 2.5 percent. This sulfur appears as sulfur dioxide and some sulfur trioxide when the coal is burned. To reduce the sulfur oxides, a coal with low sulfur content could be chosen. However, much of the low sulfur coal is reserved to be used as coke by the metals industries. The major deposits available for fuel have a lower heat value than the bituminous coal in use, and are often far from the potential users.

In spite of these problems, use of coal to supply most electric power in the near future remains highly desirable. Meeting the sulfur oxides standard for air quality will require development by coal users of the available options as to method of control. These include switching use to low sulfur coal or other low sulfur fuel, removing sulfur from coal, and removing sulfur oxides from the flue gases. Each of these options has a number of technical approaches and of course combinations of options are possibly desirable in specific situations. At present, no single mthod appears to be superior for all. The national practice in 1978 can be expected to include many control methods. Economics and technical development will dictate the strategy mix.

II. EMISSION CONTROL

A. Control of Particulates

Coal-fired steam-electric plants generally use coal ground to a fine powder before injection. When the powder reaches the flame, it burns, creating a fine particulate that flows with the exhaust gases to the stack.

The removal of particulates from stack emissions is a well-established practice. Coal-fired steam-electric power plants are normally fitted with electrostatic precipitators. Removal efficiencies up to 99 percent are possible, with 97.5 percent being common. At this latter efficiency, a 1000 megawatt electric plant emits about 5200 tons of particulate per year.

Oil combustion, because of the low ash content of most oils, does not require emission control to meet most standards. However, several electrostatic precipitators are on order for oil-fired plants, and several coal-fired plants with electrostatic precipitators have switched to use of oil and continue to operate precipitators. An electrostatic precipitator on an oil-fired plant permits use of oil with high-ash content, and is an insurance in the event of soot emission as a result of faulty combustion.

B. Control of NO_x Emissions

Power plants produce nitrogen oxides, particularly nitric oxide (NO), in concentrations up to 1000 ppm. This pollutant is formed from the nitrogen and oxygen of the air in the intense heat of the firebox. Because it is sensitive to temperature and amount of excess air, several design methods of control are available. The fuel and air can be mixed at a slower rate, lowering gas temperature and reducing the reaction rate. Two-stage combustion is effective in reducing temperature and excess air, thereby limiting the reaction. Recycle of flue gases has also been shown to be effective. With these methods, a reduction of 90 percent appears feasible for gas and oil-fired plants. Control of NO_x from pulverized-coal-fired plants, however, requires further development.

C. Control of Sulfur Dioxide Emissions

Control technology for this pollutant lacks an extensive history of operation. There are more than fifty processes in various stages of development, but only a handful are developed to the point where performance and cost can be estimated with any certainty. Four of these scrubbing processes for removal of sulfur dioxide are in operation or on order for power plants.

Of 29 operating or proposed full-size scrubbing systems for power plants, 21 are based on variations of the wet lime or limestone scrubbing process. In this process, the flue gas, laden with sulfur dioxide and some sulfur trioxide, passes through a slurry containing ground limestone which in some variations has been calcined to improve its reactivity. The calcium carbonate of the limestone reacts with the gas to form calcium sulfate and release carbon dioxide. The calcium sulfate is removed as a sludge in a settling pond, and the slurry is usually recycled to the scrubber. Efficiency of sulfur dioxide removal is about 70 to 90 percent. In general, particulate removal, as by an electrostatic precipitator, is not considered necessary since the limestone scrubbing process removes about 99 percent of particulates.

The magnesium oxide process is installed on one plant and planned for four others. This process relies on magnesium oxide to combine with the SO_x gases. Unlike the products of the limestone scrubbing process, the magnesium salts may be processed economically to obtain sulfuric acid for sale and magnesium oxide for return to the system. Because of the low value of the acid, relative inexperience with this system, and its higher initial costs, it is not as popular as limestone scrubbing.

The catalytic oxidation process is a modification of the well-known contact process for sulfuric acid production. The flue gas flows through a fixed catalyst bed where the sulfur dioxide is oxidized at a high temperature to sulfur trioxide. This is then reacted with water in an absorption tower to form sulfuric acid. A disadvantage of this process is that an electrostatic precipitator or other high efficiency particulate remover must be installed upstream of the desulfurization unit. Against this, an obvious advantage is that no solid reactants need be entered into the system, as was required in other processes. An experimental prototype of this system has recently been retrofitted to a 100 megawatt power plant.

Two power plants are to be fitted with flue gas treatment systems based on the sodium base scrubbing process. In this process, the sulfur dioxide in the flue gas is absorbed into a mixed solution of sulfite, bisulfite, and sulfate salts of sodium. Some of the sulfur dioxide reacts to form soluble sulfates; much of it reacts with sodium sulfite and water to form sodium bisulfite. The solution is then evaporated, drawing off the sulfur dioxide and water in a reverse of the reaction, thereby separating the sulfur dioxide from the rest of the flue gases and permitting its processing to sulfur or sulfuric acid. Efficiency of this regenerative process is anticipated to be at least 90 percent. A drawback is the production of sodium sulfate from some of the sulfur dioxide, as well as other contaminants. These must be removed from the regenerated solution and discarded.

Use of a flue gas scrubbing system entails a cost equivalent to a premium of $4 to $7 per ton of coal. A disadvantage of desulfurization systems until recently has been their uncertain reliability, with a history of erosion and corrosion problems. Another problem, to a utility, might be a relative difficulty in obtaining permission to pass on investment costs to the consumer, for rates are more easily adjusted when fuel costs vary than when capital investments are made.

III. FUEL SWITCHING

These considerations will encourage users of fossil fuels with high sulfur problems to switch to fossil fuels with low sulfur. Small plants, especially, will follow this alternative. Many large steam-electric plants will switch to low sulfur oil or low sulfur coal, if it is available in sufficient quantity at a competitive price.

Deposits of low sulfur coal (less than 1% sulfur) are mined in two principal locations in this country. The western subbituminous supply is in Wyoming and Montana. In 1970, about 16 million tons were produced. By 1975 a capacity of about 55 million tons is planned in these States. Production could increase to 90 million tons or more, if mining and reclamation regulations can be developed which do not prohibit the necessary stripmining. The coal is near the surface in seams over 25 feet thick, and can be recovered cheaply by strip mining, as compared with the more expensive underground mining. The deposits are sufficiently vast that the cost per ton will not be affected by the demand. Costs at the mine are expected to be under $3 per ton.

To this must be added very large transportation costs. The nearest major market for low sulfur coal is the Chicago area, some 1200 miles away. Development of the unit-train concept has reduced transportation costs significantly for long distance hauling. A cost of about $6 per ton for the 1200 mile trip by unit-train will raise the delivered fuel cost to under $9 per ton. This total is to be compared with recent coal costs of $6.50 per ton in the Chicago area.

In the eastern part of the country, low sulfur coal deposits are concentrated in western Virginia and the adjoining parts of West Virginia and Kentucky. Production in 1970 was about 70 million tons, disregarding the export and coking coal. The increase in production will depend on the increase in price per ton. Unlike western supplies, eastern supplies of low sulfur coal become increasingly difficult to mine as the demand is increased.

An increase in annual production to 120 million tons is estimated to result in an increase from the recent price of $8 to $10 per ton in 1978. This may be compared with recent high sulfur coal costs of about $5 per ton.

These figures suggest an economic incentive to develop new mines for low sulfur coal. Limitations to this development will, however, act both on eastern and western mines. The western development will be limited to supply markets within distances with acceptable transportation costs. The eastern development will be limited by the rising price of each ton of increased capacity.

As well as increase in fuel cost, a utility choosing to switch from high to low sulfur coal will encounter capital costs to convert plant burners. Modern steam-electric plants are tailored to optimal burning of a specific coal; shifting to another requires costs depending on burner design. Most difficulty occurs with a wet-bottom burner, where much of the ash is removed as a hot liquid. The ash of low sulfur coal usually has higher fusion temperature than that of high sulfur coal; as a result extensive modification, costing over $35 per kilowatt, is required. About 85 million tons of coal per year are burned in wet bottom boilers. For dry bottom burners, the modification cost is more typically $12 per kilowatt of capacity.

Fuel oil has long been an option for fossil fuel use. In 1970, electric utilities consumed 332 million barrels of fuel oil, and 2 billion barrels were consumed as fuel for industrial, household, and commercial uses. (Four barrels of oil are roughly equivalent in heat value to one ton of coal.) U. S. production of crude oil is currently not enough to supply this growing use, plus fuels used in transportation. The added requirements must be imported until synthetic processes become feasible. Because gasoline demand is not proportionately as heavy in the rest of the world, foreign refineries produce large quantities of residual fuel oil, without further processing it into gasoline and distillate. This residual fuel oil, available for import, usually requires desulfurization.

Many coal-fired plants, especially in the Northeast, have been converted to burn low sulfur fuel oil, which is in short supply. Indeed, current practice in this region is to design fossil fuel plants for easy conversion between coal and oil. Thus, a plant could have been converted to oil when low sulfur coal is unavailable and returned to coal use later when mines open up or a flue gas scrubbing system seems more economical

IV. OTHER OPTIONS

In the broader view, air quality standards raise the costs of fossil-fuel steam electric plants, raising the attraction of a number of alternatives. For the short term, many of these may be neglected because of the extensive research and development that will be required if they are to be commercially competitive. This group of long term options includes methods for harnessing wind, sunlight, tides, and thermal profiles in the ocean. While important applications of these methods exist today, their long-term potential certainly lies beyond 1978.

The option of using natural gas would provide energy with acceptable levels of pollutant emission. In 1971, natural gas provided 29% of steam-electric power, 42% of household and commercial heat and 46% of industrial heat. For small installations, this option is preferable to expensive emission controls. For large installations such as steam-electric plants, the short supply of natural gas, evidenced by sporadic curtailment of service and by rising prices, will preclude this option. By 1978, many steam-electric plants will have been forced to switch away from natural gas, and usage in this sector will decline from 4 to 3.5 trillion cubic feet, unless higher prices stimulate production. Import of natural gas, liquefied for ocean transport, is one option being adopted to fill the demand for natural gas, although this liquefied natural gas is several times more expensive at the point of delivery than domestic natural gas.

To augment the supply of natural gas, coal gasification is being undertaken. This process can also be an alternative to flue gas scrubbing, Although the hot coal gas has to be cooled to permit sulfur removal. The gas could then be used in a power plant converted to this fuel, or in a combined cycle plant. The combined cycle, using coal gas in a gas turbine and using the hot exhaust to provide heat energy for a steam boiler, delivers efficiencies up to 50%, as compared with conventional plant efficiencies around 40%. For an existing plant, the conversion cost would be about $115 per kilowatt, and the cost of low BTU gasification would be about 35¢ per million BTU. Considerable development of this option will take place in the next five years. Liquefaction of coal with removal of sulfur, is also being developed as a source of synthetic gasoline, petroleum products, and boiler fuel.

A more immediately applicable process for removing sulfur from certain grades of coal is physical desulfurization, or "deep cleaning" of coal. The coal is first crushed, to expose pyritic sulfur, and the exposed pyrites are then removed by flotation or washing. This process is well-developed, and was described in Chapter 5. The cost increase, for Eastern coal, averages $2 per ton. Only a small upgrading, as a result of removal of up to one-third of the sulfur, is possible. This process is not expected to be extensively used, since most of the coal susceptible to physical desulfurization already meets sulfur regulations for some users.

V. HOUSEHOLD, COMMERCIAL, INDUSTRIAL HEATING

A. Household and Commercial

Household heating and cooking, and commercial space heating uses of fossil fuels are projected to consume 11.4 million tons of coal, 1120 million barrels of oil, and 9 trillion cubic feet of gas in 1978. The small and declining use of coal will doubtlessly be further reduced by switching to the less polluting fuels, oil and gas, in response to the SIP requirements. This switch will require capital to convert the coal-fired boilers. The cost will range from $1,000 to $260,000 because of the large range of boiler sizes and types. Very small boilers, such as found in household heating plants, will not require conversion or switching. No costs of control were assigned to these.

B. Industrial Heating

Industry uses fossil fuels for space heating, process heating, and moving machinery. Industrial use of fossil fuels is projected to consume 166 million tons of coal, 715 million barrels of oil, and 11 trillion cubic feet of gas in 1978.

C. Costs

New equipment will be needed to convert 565,000 commercial and industrial boilers, of which 127,000 will be switched from coal burning to oil burning. The investment cost is estimated to be $879 million.

Annual costs include increased costs for low sulfur coal and oil. With capital costs and depreciation, the total annual cost for commercial and industrial boiler emission control in 1978 is estimated at $1,342 million.

VI. STEAM-ELECTRIC PLANTS

A. Strategy Selection

Electric utilities, particularly those with coal-fired plants, will analyze the various strategies presented in the previous sections for sulfur dioxide control. Each will select the alternative that complies with SIP regulations and has the most attractive cost, availability, and convenience of use.

Some generalizations can be made. First, where the premium for using low sulfur coal is not above that of flue gas desulfurization, the utility will elect to convert. When the plant is old, or the conversion costs are high and the retrofit of a desulfurization system is also difficult, the utility MAY switch to fuel oil.

The projected use of coal by the utilities in 1978 is 430 million tons. About 175 million tons of low sulfur coal (under 1%) will be used, with an additional 10 million tons washed to reduced their sulfur content. Utilities will use about 120 million tons of medium and high sulfur coal as well. This leaves a demand for 125 million tons to be met by coal burned with stack gas cleaning equipment to remove sulfur oxides.

B. Costs to Meet Regulations

For an individual steam-electric plant, the cost on a mills per kilowatt hour basis of air pollution abatement will depend on many factors and range widely from any average that can be presented. Average costs for the various strategies possible have been presented in previous sections along with the description of each strategy. The costs, for a specific plant, can generally be expected to be higher when the plant must be retrofitted with extensive new equipment such as a limestone flue gas scrubber. In contrast with retrofitting older plants, costs for more modern plants will be less, especially with the economies of size of the larger new plants.

Switching from high sulfur bituminous coal to low sulfur coal of low heat value, such as the Western subbituminous deposits, will result not only in a conversion cost, but a loss of generating capacity. Depending on boiler design, this loss could be from 5 to 15 percent, if modifications cannot be made to allow for increased throughput capacity for coal. Replacement of this loss by building of additional coal-fired plants would cost about $300 per kilowatt. The affected utility might find its capacity reserve margin so low that the new capacity would be needed sooner than coal-fired plant construction time would permit. Then, a peaking unit with low capital costs but high fuel costs would be required.

In addition to capacity loss, switching to low sulfur coal involves variable boiler conversion costs, as discussed earlier, roughly from $12 to $35 per kilowatt. The average cost of conversion will be at the low end of this range, since plants faced with high conversion costs will tend to select other strategies.

The low sulfur coal itself will cost the utility more, as discussed earlier. An increment of $6 per ton is used in this report, and amounts to an annual cost of 2.0 mills per kilowatt-hr. The individual plant costs will vary around this, as described earlier.

Flue gas scrubbing system costs depend on the process chosen, the size of the steam-electric plant, the problems of retrofitting, the ease of disposal of sludge, and future developments that will doubtlessly affect design, installation, and performance costs. Existing estimates of costs vary widely, in view of the developmental nature of this technology.

In general, both capital and operating costs are lowest for the wet lime/limestone scrubbing process, of the four processes discussed above. Capital costs range from $30 to $65 per kilowatt for present processes, and annualized costs range from 1.5 to 3.0 mills per kwhr.

Comparison of the two leading strategies for sulfur dioxide control can be made on the basis of the average costs cited above. Per kilowatt, a utility selecting to switch could have a lower capital requirement than a utility selecting to scrub flue gases, provided that the boiler design was compatible, and that the lost generating capacity was not an immediate problem. The utility selecting the scrubbing alternative would, in general, have a lower operating cost, assuming no severe technical or waste disposal problems.

Switching to oil presents some boiler conversion costs, a cost in higher fuel price in many instances, and an uncertainty in fuel supply. The price of oil depends on access to refineries, and therefore on location of the steam-electric plant. A utility on the east coast could switch, for example, from coal at $10 a ton to oil at $4 a barrel. This would increase the energy cost by 2.8 mills per kwhr. A utility further inland where coal is cheaper and oil dearer would pay perhaps 0.8 mills per kwhr above this. Boiler conversion costs to convert to oil are estimated at $20 per kilowatt.

Oil burning plants will elect to switch from high sulfur oil to oil of low sulfur content. The incremental cost to obtain low sulfur fuel oil is about 85¢ per barrel.

The cost of an electrostatic precipitator for particulate emission control depends on plant size, efficiency requirements, and quality of fuel to be burned. Typically, investments are between $4 and $10 per kilowatt for high efficiency (99.5%) precipitators. Operating costs are much lower than they are for other forms of particulate control. Utility practice has been to include an electrostatic precipitator on coal-fired steam electric plants. When flue gas scrubbers are used, this is not necessary. Credit against the cost of the scrubber can therefore be taken for omission of the precipitator.

These costs are summarized in Table 6-2. A total capital investment of $2900 million is anticipated in 1978. Annual costs due to pollution control are estimated at $1860 million.

Table 6-5. 1978 Cost Estimates for Steam-Electric Plant Emission Controls (Millions of Dollars)

Control	Investment	Annualized
Use of and conversion to low S coal	160	420
Use of and conversion to low S oil	220	770
Stack scrubbing	2750	680
Credit for flyash control	(230)	(10)
Totals	2900	1860

VII. EMISSIONS

Pollutant emission by fossil-fuel steam-electric plants includes all of the six pollutants for which ambient air quality standards have been set, although normally negligible amounts of photochemical oxidants are emitted. Carbon monoxide emissions, typically below one pound per ton of coal burned, are also of minor importance. Estimates of the principal pollutant emissions are summarized in Table 6-3.

The disposal of waste products from stack gas desulfurization systems remains a major problem with serious environmental consequences. Based on the control strategy outlined above, 23 million tons per year of throwaway sludge would be produced. This corresponds to a potential land requirement of 80 square miles, assuming a 20-year storage requirement and ponding to a 10-foot depth. We have included disposal costs of $2 per ton for this material, but the technical problems of transportation, prevention of water pollution, and land requirements have not been studied for this report. Development of recycling systems that are competitive with throwaway systems would solve the problem.

Fly ash is an ever increasing problem for solid waste disposal. Readily controllable by modern electrostatic precipitators, annual recovery is now 30 million tons and is expected to reach 50 million tons by 1980. However, few uses for it currently exist. Because of its uniform particle size and composition, fly ash could be used in building and highway construction. It may be used agriculturally for improving soil texture and, being alkaline, as a limestone substitute.

Table 6-3. Emissions (Tons) Steam-Electric Power Plants

Emissions	Particulates	SO_2	NO_x
In 1973	3,194,000	23,465,000	11,918,000
In 1978			
w/o Additional Control	4,083,000	28,150,000	16,053,000
w/Additional Control	498,000	5,260,000	13,637,000
Difference	3,585,000	22,890,000	2,416,000